ENVIRONMENTAL

PUBLIC HEALTH RISK ASSESSMENT OF THE IRVING OIL REFINERY UPGRADE

- FINAL TECHNICAL DOCUMENT -

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1

2.0 BACKGROUND 2
- 2.1 The Irving Oil Refinery Upgrade Project 2
- 2.2 Overview of Saint John Air Quality Issues 2

3.0 PUBLIC CONSULTATION 5

4.0 METHODS USED IN THE PUBLIC HEALTH RISK ASSESSMENT OF THE IRVING OIL REFINERY UPGRADE METHODS 8
- 4.1 Health Risk Assessment Methods 9
  - 4.1.1 Problem Formulation 11
    - 4.1.1.1 Site Characterization 11
    - 4.1.1.2 Identification of Chemicals of Potential Concern 12
    - 4.1.1.3 Receptor Selection and Characterization 14
    - 4.1.1.4 Selection of Exposure Pathways and Scenarios 16
  - 4.1.2 Exposure Assessment 24
  - 4.1.3 Toxicity (or Hazard) Assessment 26
  - 4.1.4 Risk Characterization 40
    - 4.1.4.2 Consideration of Chemical Mixtures 43
- 4.2 Public Health Assessment Methods 43
  - 4.2.1 Identification of Risks and Public Health Concerns 43
    - 4.2.1.1 Public Health Risks and Community Outreach 44
    - 4.2.1.2 Identification of Available Data Sources 45
  - 4.2.2 Predicted Change in Public Health Impact 46

5.0 HEALTH RISK ASSESSMENT RESULTS AND DISCUSSION 47
- 5.1 Polycyclic Aromatic Hydrocarbons 48
- 5.2 Volatile Organic Compounds (VOCs) 52
  - 5.2.1 Mercaptans / Total Reduced Sulphur Compounds 55
    - 5.2.1.1 Total Reduced Sulphur Compounds 56
    - 5.2.1.2 Mercaptans 57
  - 5.2.2 Irritant Effects of Aldehydes 59
- 5.3 Combustion Gases
  - 5.3.1 Sulphur Dioxide 61
  - 5.3.2 Nitrogen Dioxide 68
  - 5.3.3 Carbon Monoxide 75
- 5.4 Particulate Matter 81
  - 5.4.1 Particulate Matter - PM_{10} 81
  - 5.4.2 Particulate Matter - $PM_{2.5}$ 84
  - 5.4.3 Total Suspended Particulate (TSP) 87

TABLE OF CONTENTS (Continued)

Page

5.5 Secondary Reaction Products from Various Air Emissions 91
  5.5.2 Acid Aerosols 94
5.6 Additional Exposure Pathways 100
  5.6.1 Potential Exposure from Swimming in Nearby Water Bodies 100
  5.6.2 Ingestion of Fish from Nearby Water Bodies 101
  5.6.3 Ingestion of Game Meat from the Vicinity of the Refinery 102
  5.6.4 Ingestion of Chemicals on Snow 103
5.7 Comments on Other Specific Community Concerns 105
  5.7.1 Predicted Impact of Refinery Upgrade on Noise Levels 105
  5.7.2 Potential Visual Effects 108
  5.7.3 Predicted Impact of Refinery Upgrade on Night Light Levels 109
  5.7.4 Qualitative Discussion of Odour Impacts Associated with the Refinery Upgrade 109
  5.7.5 New Technologies 111
  5.7.6 Upset and Accident Scenarios 113
  5.7.7 Flaring 114
  5.7.8 Potential Effects on Surface Water and Well Water Quality 115
5.8 Conservative Assumptions in the Assessment 116
5.9 Limitations and Uncertainties in the Assessment 118
5.10 Summary of Results of the Risk Assessment 119

6.0 PUBLIC HEALTH ASSESSMENT RESULTS AND DISCUSSION 122
6.1 Identification of Risks and Public Health Concerns 122
  6.1.1 Review of the Literature of Regional Interest 122
  6.1.2 Current Public Health Status of Saint John Community 125
6.2 Predicted Change in Public health Impact 135
  6.2.1 Cancer Outcomes 135
  6.2.2 Non-Carcinogenic Health Outcomes 139
6.3 Discussion 141
  6.3.1 Current Public Health Status of Saint John 141
  6.3.2 Predicted Public Health Benefit from IOL Refinery Upgrade 145

7.0 COMBINATION OF HUMAN HEALTH RISK ASSESSMENT AND PUBLIC HEALTH ASSESSMENT 148

8.0 CONCLUSIONS

9.0 VALIDATION AND FOLLOW-UP 152

10.0 REFERENCES 156

LIST OF APPENDICES

APPENDIX A	PUBLIC CONSULTATION
APPENDIX B	CONSTRUCTION ISSUES
APPENDIX C	LIST OF DATA AND INFORMATION SOURCES REVIEWED AND / OR CONTACTED FOR THE RISK ASSESSMENT COMPONENT OF THE PUBLIC HEALTH RISK ASSESSMENT
APPENDIX D	VOLATILE ORGANIC COMPOUND (VOC) SCREENING
APPENDIX E	TECHNICAL INFORMATION RELATED TO THE EXPOSURE ASSESSMENT
APPENDIX F	PHYSICAL/CHEMICAL PROPERTIES OF SELECTED CHEMICALS
APPENDIX G	APPLICATION OF MOEE (1997) METHODOLOGY TO THE TOXICITY ASSESSMENT OF POLYCYCLIC AROMATIC HYDROCARBONS
APPENDIX H	MAP OF HEALTH REGIONS IN NEW BRUNSWICK
APPENDIX I	QUANTITATIVE MODELLING RESULTS
APPENDIX J	CRUDE INCIDENCE RATES
APPENDIX K	CRUDE MORTALITY RATES
APPENDIX L	OUTLINE OF A COMMUNITY HEALTH PROGRAM FOR SAINT JOHN
APPENDIX M	GLOSSARY

PUBLIC HEALTH RISK ASSESSMENT OF THE IRVING OIL REFINERY UPGRADE IN SAINT JOHN, NB

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PUBLIC HEALTH RISK ASSESSMENT OF THE IRVING OIL REFINERY UPGRADE IN SAINT JOHN, NB

PROJECT SUMMARY

CANTOX ENVIRONMENTAL was contracted to conduct a Public Health Risk Assessment of the Irving Oil Limited (IOL) Refinery Upgrade in Saint John, New Brunswick by the Department of Health and Community Services. The Public Health Risk Assessment was conducted jointly by CANTOX ENVIRONMENTAL and Health Risk Management Group Inc. of Washington D.C. Northcote Group of Fredericton, NB provided valuable assistance with public consultation activities.

The primary purpose of the Public Health Risk Assessment was to provide an evaluation of the potential effects (positive, negative or neutral) of the IOL Refinery Upgrade on the health status of people living in Saint John. The terms of reference of the study stipulated by the Public Health Risk Assessment Working Group, were not to conduct an overall study of air quality issues in the Saint John air shed, rather they focussed specifically on the IOL Refinery Upgrade. The Working Group is chaired by a NB Assistant Deputy Minister of Health and includes representatives from the NB Department of Health and Community Services, the NB Department of Environment, Irving Oil Refinery Limited, the City of Saint John and the community of Saint John. Concerns and issues raised by the public were identified and incorporated into the assessment through an extensive, on-going public communication and consultation program.

What is a Public Health Risk Assessment and how was it conducted?

A Public Health Risk Assessment is a scientific study, using the best available biological, medical and environmental science, of the possible risks of adverse health effects resulting from exposure to specific chemical emissions. These potential risks are put into perspective by comparing the public health status of the community being evaluated to the health status of other similar communities. The Public Health Risk Assessment of the Irving Oil Refinery Upgrade consisted of two main components: a *health risk assessment* component and a *public health assessment* component.

The assessment followed standard and scientifically accepted procedures for conducting human health risk assessments and public health assessments. These procedures included the following major steps:

Human Health Risk Assessment

- Identification and selection of chemicals of potential concern associated with IOL Refinery Upgrade emissions and as expressed by the community. The chemicals were selected by screening ambient air monitoring data from the Saint John region, IOL Refinery emission data and literature identifying emissions from other refineries, and included the following: polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs), combustion gases (*i.e.*, sulphur oxides, nitrogen oxides, carbon monoxide), particulate matter, ozone and acid aerosols (arising through the combination of combustion gases and particulate matter).

- Identification of the characteristics of people in the community who would have the greatest potential exposure to the emissions and the greatest sensitivity to these emissions. These characteristics were then combined to represent receptors (hypothetical people) assumed to live near the IOL Refinery with the greatest likelihood of responding to the emissions.

- Identification of exaggerated, but still possible, exposure scenarios of the routes and pathways of exposure by which the representative community receptors would come into contact with the emission of potential concern. Four separate exposure scenarios were evaluated:

  1. Existing Ambient Scenario: Evaluation of the potential exposures to ambient concentrations of emissions in various areas of the communities based on the current ambient air monitoring data collected near the IOL Refinery.

  2. Existing Study Area Scenario: Evaluation of the potential exposures of the selected receptors to predicted ground level air concentrations of emissions from industrial sources near the refinery, including the IOL Refinery in its present state (*i.e.*, without the upgrade).

  3. Future Study Area Scenario: Evaluation of the potential exposures of the selected receptors to predicted future ground level air concentrations of emissions from industrial sources near the refinery, including the IOL Refinery following the upgrade.

  4. Background Scenario: All of the emissions considered in this assessment can be found within the environment, independent of their presence in emissions from the IOL Refinery Upgrade, either from natural sources or other sources related to a wide range of human activities (*e.g.*, residential heating, other industries, vehicle exhaust, long range transport of air pollution from other locations). Therefore, the background exposure scenario was based on calculated exposures of the selected receptors to the concentrations of the same emissions considered in the three Saint John region scenarios that would typically be found within an urban environment. The sole purpose of the inclusion of an assessment of this background scenario was to provide a benchmark or reference for comparison to the assessment results from the other scenarios.

- Identification of the potential hazards that could result from exposure to the selected emissions, and identification of the concentrations of these emissions that would not result in adverse health effects or would likely be without appreciable risk of adverse health effects.

- Calculation of a daily exposure rate for each receptor and each chemical, based on parameters such as, how much air is breathed, how much time would be spent inside and outside, how much local produce is consumed, *etc*.

- All of the above information was entered into a mathematical model to enable an assessment of whether exposure to emissions from the IOL Refinery Upgrade would be likely to adversely affect the public health of the community.

In addition, qualitative assessments were conducted for numerous issues that were either identified as being of concern during public consultation activities or were required as part of the terms of reference for this assessment. These issues included noise, potential visual effects, light, odour, new technologies, flaring, potential effects on surface water and well water quality, and possible psychosocial effects that could affect health.

Public Health Assessment

- Identification of Risks and Public Health Concerns: This step enabled the identification of health-based questions and community concerns. It involved speaking with the community and interested parties, and the identification of data that details community health and risk factor information (*e.g.*, scientific studies specific to the community, hospital admission/discharge rates for the community, disease registries, *etc*.).

- Predicted Change in Public Health Status: This step involved a detailed assessment of current community health status by reviewing the data sources identified in the prior step. This information included disease incidence rates and frequencies of hospital admissions and discharges for respiratory illnesses, emergency room visits, *etc*. This information on the health status of the community was combined with the results of the health risk assessment to enable an assessment of whether there would be any changes in the public health status of the community related to emissions from the IOL Refinery Upgrade.

What are the conclusions of the assessment?

The overall conclusion of the Public Health Risk Assessment was that emissions related to the IOL Refinery Upgrade will not result in either measurable adverse outcomes or measurable benefits, and in other words, the Upgrade is predicted to have a neutral effect on the public health of the community. The IOL Refinery Upgrade will reduce the concentrations of sulphur dioxide (SO_2) within the air, but will increase concentrations of particulate, nitrogen oxide (NO_x), and carbon monoxide (CO). The predicted future concentrations of these chemicals are either less than air quality guidelines and/or within the concentration ranges already reported in ambient monitoring programs. Since the IOL Refinery is only one of a number of industrial facilities within the Saint John air shed, and since many of the predicted changes are small, their overall impact on air quality will likely not be measurable. Hence, the predicted impact on public health is neutral. This conclusion is based on a number of assumptions which are considered to be protective of public health. Furthermore, additional emission controls to the IOL Refinery Upgraded units, beyond those proposed, would not result in measurable improvements in the public health of the community, assuming that the data and assumptions used in the assessment were valid.

Another conclusion from the Public Health Risk Assessment was that the ground level air concentrations of various emissions in the community have historically, and will in the future, exceed specific air quality objectives established to avoid public health outcomes in people exposed to such concentrations of these substances. These exceedances were predicted specifically for SO_2 and acidic aerosols (SO_2 combined with airborne particulate matter). It should be noted that there are presently no regulatory air quality objectives for acid aerosols, and, as a result of this, a provisional guideline value was derived by the study team. These exceedances in air quality guidelines would be expected to cause adverse health outcomes in sensitive people (*i.e.*, those with various respiratory conditions like asthma, COPD, respiratory allergies, emphysema) in the community. The adverse health outcomes predicted would include such undesirable responses as coughing, respiratory tract irritation, difficulties breathing, and related symptoms typical of asthma. The duration of such symptoms would be directly related with the duration of exceedances of the air quality guidelines.

The IOL Refinery Upgrade was predicted to cause a small decrease in ground level air concentrations of SO_2 in the communities surrounding the refinery because of the predicted reduction in stack emissions of SO_2 following the upgrade. The reductions of ground level air concentrations of SO_2 were proportionately less than the percentage decrease projected for stack emissions. This observation indicates that the IOL Refinery is a smaller contributor to the ground level air concentrations of sulphur dioxide than the combination of other industrial and non-industrial sources in the Saint John region.

Ambient concentration of the other combustion gases evaluated (*i.e.*, nitrogen oxides, carbon monoxide) and particulate matter, are projected to increase as a result of the IOL Refinery Upgrade. Projected future concentrations of these chemicals / chemical groups as a result of the IOL Refinery Upgrade would not be expected to result in measurable adverse health outcomes in the community, since they are either less than air quality guidelines, and/or the projected increases are within the concentration ranges already reported in ambient monitoring programs.

The public health assessment identified elevated risks for lung cancer and hospitalizations for mental disorders in Saint John compared to Fredericton and the province of New Brunswick. The prime reasons for the high incidence of these diseases in Saint John were use of tobacco products resulting in lung cancer, and increased availability and accessibility to medical facilities in Saint John. There are residual risk factors beyond those included above for these health outcomes, and these residual factors should be investigated

What further information needs to be collected to validate the results of the assessment?

A number of assumptions and extrapolations were made to enable the evaluation of potential public health impacts predicted following the IOL Refinery Upgrade. These assumptions were necessary in order to evaluate the facility upgrade which is not yet operational (*i.e.*, a prospective or future study). The study team made every effort to ensure that the assumptions followed were protective of health, and that the data used adequately represented conditions at the site, so that any potential risks to public health would not be underestimated. It is standard procedure to confirm or validate some of the assumptions used in an assessment of this type, once the facility is built and operating, in order to reduce uncertainty in the assessment results. Therefore, the following validation steps have been recommended by the study team:

- Collect data on emission rates and ambient ground level air concentrations of SO_2, NO_x, CO, and various sizes of particulate matter once the IOL Refinery Upgrade is operational. Stack emissions should be analyzed to enable comparison to the PAH profile used in the assessment;
- Collect data to characterize the specific types of VOCs present, and to confirm the assumption that VOCs released from the IOL refinery (*e.g.*, fugitive and stack emissions), will not increase to a significant degree as a result of the Upgrade;
- Confirm predicted future health status of the community through a continuation of the public health assessment in the future;
- An appropriate odour monitoring program, similar to that conducted historically, should be conducted once the upgrade is operational. This program should be linked and coordinated with the fugitive emission monitoring and analysis program outlined above for VOCs to validate the assumptions made that the concentrations of these emission will not change in the community once the IOL Refinery Upgrade is operational;
- The IOL program in place for training staff and bringing the new technologies in the upgrade on line should be communicated with the public to address concerns regarding possible failures;
- IOL should improve communication with the public regarding their maintenance, and resulting emergency-response programs. This activity would help address the assumption in the PHRA that potential psychosocial issues related to public health will be reduced once the IOL Refinery Upgrade is operational;
- Noise levels are not expected to change once the Upgrade is operational. However, an appropriate program, such as that conducted historically, should be implemented to monitor noise from the upgraded facility so that an appropriate noise management program can be implemented if required.
- It is not expected that the intensity of light emissions from the refinery will change once the upgrade is operational. This conclusion should be verified, and if nighttime night levels change significantly as a result of the upgrade and this poses concern to local residents, options to mitigate this problem should be identified and implemented

Collection of these data will then be used to test the validity of the conclusions of the assessment. The Working Group informed the study team that all of the above items will be verified as these items are either currently requirements with which Irving Oil Limited must comply or have already addressed, or items which the Department of Health and Community Services has committed to addressing (*i.e.*, continuation of the public health assessment in the future to monitor future health status of the community).

Although not related specifically to any aspects of the IOL Refinery Upgrade, it is important that follow-up from other scientific reports be undertaken, for example, historical reports with respect to the evaluation of ambient chemical concentrations and the health status of the community in general.

The Public Health Risk Assessment also concluded that a Public Health Management Program would be extremely beneficial in the Saint John region. Such a program would be valuable in addressing the various validation issues outlined above, but more importantly, in addressing the factors identified in the assessment not related to the IOL Refinery Upgrade that were concluded to be associated with adverse public health outcomes now and in the future, specifically ground level ambient air concentrations of SO_2 and acidic aerosols. The Public Health Risk Assessment concluded the IOL Refinery Upgrade would not result in measurable impacts on these air quality issues; however, that there was evidence of such air quality exceedances in the Saint John region. Public Health Management Programs involve the integration of the information obtained through health risk assessment models applied to various point sources, and through public health assessment (as was conducted for the IOL Refinery Upgrade) to enable the determination of the relative causal attributions of the diseases in a community. Other industrial, municipal and public institutions would have to be included in such a program. These sources of information, plus the specific requirements of the community, are combined to enable the development and prioritization of initiatives to improve the health status of the community. Such a program uses the results of public health risk assessment models, public health assessment of disease status and risk attribution methods to prioritize, develop and implement specific public health management initiatives.

Further details can be found in the Main Report of the assessment.

1.0 INTRODUCTION

CANTOX ENVIRONMENTAL INC. was contracted to conduct a Public Health Risk Assessment (PHRA) of the Irving Oil Limited (IOL) Refinery Upgrade in Saint John, New Brunswick by the Department of Health and Community Services (DHCS). CANTOX ENVIRONMENTAL INC. (CEI) jointly conducted this project with Health Risk Management Group Inc. (HRMG) of Washington D.C., while Northcote Group of Fredericton, NB provided valuable assistance with public consultation activities. This report describes the technical results of the PHRA.

The primary purpose of the PHRA was to provide an evaluation of the potential effects, positive or negative, of the IOL Refinery Upgrade on the health status of people living in Saint John. The PHRA was one of eleven conditions listed in the Certificate of Approval to be met by Irving Oil Limited before an operating permit would be issued by the Department of Environment for the upgraded components of the refinery. It should be recognized that the PHRA was to focus specifically on the IOL Refinery Upgrade. Due to this focus, the PHRA is not an overall study of air quality issues in the Saint John air shed, nor a baseline health assessment for Saint John.

The terms of reference for this Public Health Risk Assessment were compiled by the Public Health Risk Assessment Working Group. The Working Group is chaired by a NB Assistant Deputy Minister of Health and includes officials from the NB Department of Health and Community Services, the NB Department of Environment, Irving Oil Limited, the City of Saint John and community representatives. Throughout the study, the study team (*i.e.*, CEI, HRMG, Northcote Group) sought input and guidance from the PHRA Working Group. Concerns and issues raised by the public were addressed through an extensive, on-going public consultation program.

This report contains the technical results of the PHRA. A glossary of terms is appended (Appendix M) to aid in the understanding of the information presented. In addition, a series of appendices are included to provide some detailed information concerning the data, assumptions and methods used to conduct the PHRA.

Public consultation was an important component of this PHRA. A number of meetings were held prior to initiating the PHRA to identify particular concerns and issues that the public wanted included in the assessment. In addition, the public will have an opportunity to review, discuss and comment on the technical results of the PHRA. Comments from the public on the technical results will be presented as an addendum to this report.

2.0 BACKGROUND

2.1 The Irving Oil Refinery Upgrade Project

The Irving Oil Refinery is located in East Saint John and the current certificate of approval is for the processing of 250,000 barrels of crude oil per day to produce such products as gasoline, diesel, fuel oil, asphalt, butane and propane for domestic and international markets. The refinery presently processes an average of 190,000 barrels per day (with a typical annual range of approximately 175,000 to 210,000 barrels per day) (IOL, 1999e). The currently approved nameplate capacity of 250,000 barrels/day will not change as a result of the upgrade. In order to remain competitive on an international scale, IOL must increase its conversion of low value heavy oils to higher value transportation fuels like gasoline and diesel (IOL, 1998). To achieve these objectives, the existing refinery process units will be retrofitted and upgraded, and new units will be added in order to change IOL's product mix to meet market demands. The upgrade will consist of the addition or modification of several process units and infrastructure to the existing refinery including, but not limited to the following:

- crude oil distillation unit
- residue fluid catalytic cracking unit
- alkylation unit
- sulphuric acid regeneration unit
- sulphur plant tail gas unit
- amine sulphur recovery unit
- sour water stripping unit
- pipe rack, piping, storage, blending and dispensing equipment
- cooling tower unit No. 3
- utility plant No. 2 (Part of unit 245)
- associated control buildings

(Source: IOL, 1998; NB DOE, 1999a)

In addition, some units will be taken out of service and either dismantled, or held in reserve as back-up units to enable continuous processing during maintenance procedures.

This is not the first upgrade for the IOL Refinery; it has undergone a number of previous upgrades throughout the late 1980's and early 1990's, many of which were accompanied by improvements in environmental technology (refer to IOL, 1998 for more details).

2.2 Overview of Saint John Air Quality Issues

Saint John, New Brunswick is an industrialized port city with a population of roughly 73,000, located at the mouth of the Saint John River on the Bay of Fundy. Much of the area's industry is concentrated in the eastern portion of the city (East Saint John). There are several industrial air emission sources in Saint John, including the IOL Refinery, two pulp and paper mills, two thermal generating stations, a batch mix asphalt plant, three plastics plants, and a commercial printing facility. In addition, there are non-industrial sources of air emissions associated with residential, recreational, and transportation activities. The Saint John air shed is also impacted to a significant extent by long range atmospheric transport of pollutants from central Canada and the eastern United States. NB DOE (1993) reported that approximately 82% of the air pollution in southern New Brunswick is due to long-range transport of pollutants that originated elsewhere. However, both point and mobile sources in Saint John also contribute to local ambient air concentrations.

The influence of weather patterns on air pollution and air movement in the Saint John area is highly complex. Based on 5 years of weather data from the Forest Hills monitoring station in East Saint John, prevailing winds generally travel north to north west in the winter, south to south west in the summer, with strong westerly flows in the spring and fall (Murphy *et al.*, 1996). While the Bay of Fundy tends to channel air masses in a south west to north east direction, the combination of large humid air masses and cold water creates a high incidence of fog. Fog is especially prevalent during May to September. Fog, combined with various air pollutants, is believed to be responsible for airborne acid particulates. Some of the highest measured concentrations of acidic particles in Canadian cities have been found to occur in Saint John (Saint John - Fundy ARMA, 1997).

There are also a number of inland hills, ridges and valleys which affect air movement around Saint John. Valleys can trap air masses, for example, and serve as conduits for funnelling winds. Much of the area surrounding Saint John is hilly and forested, which creates an irregular land surface. Buildings and industrial facilities, in and around Saint John, add to this surface irregularity. Such land surfaces tend to reduce local wind speeds, which can reduce the mixing and dilution of local air masses (McCarty, 1996). Temperature and the amount of sunlight also impact on weather patterns around Saint John, adding to the complexity of air movements and any associated air pollutants.

As a coastal city with a number of hills and valleys, Saint John is prone to thermal (or temperature) inversions. These inversions occur when the normal pattern of decreasing temperature with increasing altitude is interrupted by an upper layer of warm air. Since warmer air is more buoyant than cooler air, it tends to rise and the warm upper layer acts as a "lid", trapping the cooler air beneath, and preventing its dispersion via upward diffusion (Bunce, 1991). In thermal inversions, the mixing and dilution of the trapped air with other air masses is reduced. Such thermal inversions, accompanied by hot temperatures and intense sunlight, can lead to significant deterioration in localized air quality through the production of ground level ozone and other components of photochemical smog. Saint John is vulnerable to such thermal inversions from late Spring to early Fall (McCarty, 1996). The majority of poor air quality episodes in Saint John have been reported during these periods. Although thermal inversions are important contributors to air quality issues in Saint John, such episodes may be further exacerbated by long-range transport of contaminated air masses from the Central Canada and the eastern United States (NB DOE, 1999b; McCarty, 1996; CEC, 1992).

Poor air quality has long been a major issue for the residents of Saint John. A survey by CRA Inc. in 1996 indicated that the majority of Saint John residents were concerned about air quality, with many perceiving such pollutants as having an adverse impact on human health, as well as on agriculture and wildlife. In this survey, six of ten residents identified outdoor air quality as the aspect of their physical environment which was their greatest concern. The major contaminants of concern in Saint John air identified by the public in this study included sulfur dioxide, nitrogen dioxide, volatile organic compounds, particulate matter, acid aerosols, carbon monoxide, and ground level ozone (CRA, 1996).

Southern New Brunswick is one of several regions in Canada which experience frequent exceedances of ground level ozone above the National Ambient Air Quality Objective. However, monitoring and modelling data have shown that the majority of ground level ozone observed in New Brunswick originates in the north-eastern United States (NB DOE, 1999b). Some recent studies suggest an association between episodes of elevated concentrations of ground level ozone and increased hospital admissions and emergency room visits in the Saint John area (Stieb *et al.*, 1996; Burnett *et al.*, 1997).

Due to a number of actions, including control of emissions from local industry, and the institution of vehicle emission control systems, air quality in Saint John has steadily improved from the mid-1970's to the present on an annual average basis (McCarty, 1996). Average ambient air concentrations of sulfur dioxide and particulates have displayed a steady downward trend over this period. Nitrogen oxides and carbon monoxide have fluctuated more, but have remained below maximum acceptable guidelines (McCarty, 1996; NB DOE, 1999b). With the exception of ground level ozone and some short term periodic episodes of poor air quality resulting from local climate and topographic factors (*e.g.*, thermal inversions), Saint John is now generally recognized as having air quality which is as good, or better than many other major Canadian urban centres. As is the case in most Canadian cities, however, additional improvements are still needed to provide the level of air quality specified by various government regulations, and demanded by the public (McCarty, 1996).

New Brunswick's 1993 Clean Air Strategy strives to provide the best possible air quality for residents of New Brunswick, and meet the Province's responsibility to the international community to minimize the export of pollutants, while supporting a healthy economy and productive society (Saint John - Fundy ARMA Committee, 1996). As part of this strategy, New Brunswick established five Air Resource Management Areas (ARMAs), which allow for the specific environmental objectives of each region to be identified in an air management plan, based on the unique needs of each ARMA. The Saint John - Fundy ARMA Committee was the first such group to be formed in 1994. Following extensive public consultation on the Clean Air Strategy, and the need for new provincial legislation in this area, New Brunswick's Clean Air Act became operational in December, 1997. Regulations under the Clean Air Act provide the Government with improved tools and options to promote compliance and formalize procedures for public review of Certificates of Approval for major emission sources, as well as setting or revising air quality objectives (NB DOE, 1999b).

3.0 PUBLIC CONSULTATION

A prime consideration of the Public Health Risk Assessment (PHRA) was to ensure that members of the local community had an opportunity to comment on, and participate in the assessment process. The inclusion of issues related to the IOL Refinery Upgrade in the PHRA identified by the public was considered critical to the validity and usefulness of the assessment to the community. A variety of methods, as summarized below, were used to facilitate and encourage input by the public into the project.

- At the outset of the PHRA project in early May, a list of stakeholders (*i.e.*, groups / individuals with a potential interest in the study) were identified by Northcote Group. These stakeholders were then contacted to inform them of the PHRA project, its emphasis on consultation, the upcoming public drop-in session, and the availability of background information on the study. Stakeholders contacted in the initial stage of public consultation activities included:
    - Air and Resource Management Committee (ARMA)
    - Atlantic Coastal Action Program (ACAP)
    - Citizens Coalition for Clean Air
    - Conservation Council of NB
    - Department of the Environment (Saint John)
    - Environment Canada
    - Environment Committee for Saint John Common Council
    - Irving Oil King of Cats Project Community Awareness Liaison Committee
    - NB Environmental Network
    - NB Lung Association
    - Saint John Board of Trade
    - Saint John Medical Society

- On the basis of responses received through initial discussions with the above groups, a list of key stakeholder groups were identified and specific consultation meetings were then arranged by the PHRA study team with: Air Resource Management Area Committee, Citizens Coalition for Clean Air, Irving Oil King of Cats Project Community Awareness Liaison Committee, and the Department of the Environment (Saint John).

- Stakeholder meetings took place during the week of May 25th and included several members of the PHRA study team (*i.e.*, CANTOX ENVIRONMENTAL INC., HRMG and Northcote Group). Summary notes from these meetings, compiled by Northcote Group and reviewed by meeting participants, are presented in Appendix A.

- To aid discussions during these meetings, background information on the PHRA was prepared and distributed in an easy-to read format to all interested participants. This information was also made available at a subsequent 'public drop-in' (See Appendix A).

- The 'public drop-in' was held on May 27th at the Forest Hills Elementary School, which had been promoted in advance through a news release, as well as newspaper, radio and public service announcements. This four-hour session provided individual members of the community with an opportunity to ask questions, register concerns and provide input on the assessment to study team members. Two community representatives of the PHRA Project Working Group also participated at the 'drop-in' session, together with representatives from the Department of Health and Community Services. A summary report on this initial 'drop-in' is included in Appendix A.

- A similar 'drop-in' event will be scheduled following submission of this final technical report to the NB Department of Health and Community Services. At this final session, the public will have the opportunity to comment on the PHRA. Comments received from the community, together with any further responses required from the study team, will subsequently be provided as an addendum to this report.

- Concurrent with initial public consultation activity, information about the PHRA was placed on the Internet at a specific project web site, and has been updated as necessary throughout the assessment process. Interested individuals were able to use this site to download information on the project or to contact a member of the study team.

- A Community Response Telephone Line service also began operating locally during the week of May 25th and has continued throughout the project. Callers are able to contact the response line 24 hours a day, seven days a week, to leave a message, ask a question or provide a comment. Northcote Group monitors this line on a daily basis on behalf of the study team, obtains more detail on the caller's question if required, and then relays the message to a team scientist who provides a specific individual response. A detailed summary of calls received on the Community Response Line is provided in Appendix A.

- A Saint John post office box address was established as well, where community members could mail questions or comments on the PHRA for the duration of the project. To date, very little written response has been received.

- At the mid-way point of the project schedule, an eight-page newsletter was prepared and distributed in the community to provide background information on the PHRA and summarize the initial aspects of the project. The publication was delivered directly to over 3100 homes in areas surrounding the refinery, and encouraged public comment or questions through the Community Response Line, the Internet website, e-mail address or local post office box. Bulk copies of the newsletter were also placed in several Saint John locations (*e.g.*, public libraries, the Community College on Grandview Avenue, the ACAP office in Market Square). A copy of the newsletter is included in Appendix A.

- Following the submission of this final technical report to the DHCS, a second newsletter will be produced, summarizing the results of the assessment and providing the community with details on the concluding 'public drop-in' session.

The stakeholder meetings and public consultation activity to date have provided the study team with valuable information and input from the community, regarding issues and concerns related to the refinery upgrade. Some of the main issues identified by the community are summarized below More detailed information on the key issues of concern is provided in the stakeholder meeting summaries contained in Appendix A. As stipulated in the Terms of Reference for the PHRA (DHCS, 1999), concerns related specifically to construction issues associated with the refinery upgrade were recorded, summarized and forwarded to representatives of both Irving Oil Refinery Limited and the NB Department of Environment. A summary of these concerns is presented in Appendix B. Issues that fell within the scope of the PHRA were evaluated where data were available. Those issues which fell outside the scope, or had inadequate information available to address the issue, were forwarded to the PHRA Working Group for consideration and response.

PHRA issues identified from public consultation included:

- odour
- noise
- are new technologies "proven"?
- flaring
- potential effects on surface water and well water quality
- consideration of weather patterns in Saint John
- upset conditions (start-up, shut-down, accidents)
- disease incidence in the community
- psycho-social effects

A summary of exposure pathways of potential concern, as identified by the community during public consultation, included:

- ingestion of berries (*e.g.*, blueberries, raspberries)
- ingestion of home garden produce
- ingestion of "dusts/ particles" on snow by children
- swimming in near-by lakes / rivers
- ingestion of fish from water bodies in the area
- ingestion of wildlife from the area (*e.g.*, snowshoe hare, moose)
- ingestion of drinking water
- inhalation of air emissions
- ingestion of soils / dusts

Further details on these potential exposure pathways identified through public consultation are presented in the Problem Formulation stage of the risk assessment, where an exposure pathway screening process was conducted.

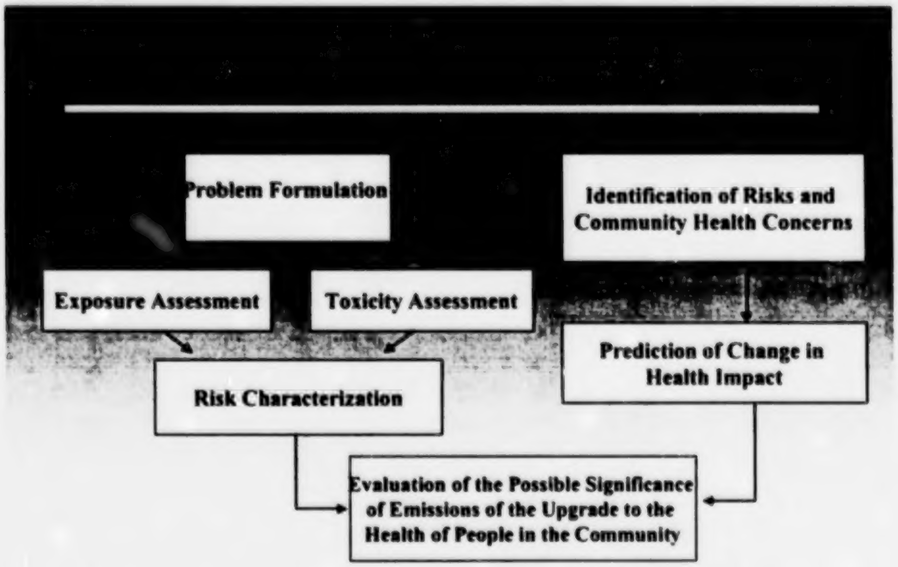
Detailed information on the activities of the community was also collected as part of the public consultation efforts (*e.g.*, amount of time spent inside and outside; amount of home grown garden produce consumed, *etc.*). This information was incorporated into the exposure assessment step of the risk assessment. In addition, community members identified several specific chemicals which were of potential concern. These chemicals were included in the assessment where data were available.

4.0 METHODS USED IN THE PUBLIC HEALTH RISK ASSESSMENT OF THE IRVING OIL REFINERY UPGRADE METHODS

A Public Health Risk Assessment (PHRA) is a scientific study of the possible risks of adverse health effects resulting from exposure to specific emissions. The estimates of these possible risks are interpreted and put into perspective by comparisons to information on the public health status of the community potentially affected by the emissions.

The PHRA of the Irving Oil Refinery Upgrade consists of two main components: a *risk assessment* component and a *health assessment* component (See Figure 1). The *risk assessment* component provides an analysis of the potential for emissions from the upgraded Irving Oil Refinery to be associated with health outcomes in people living in the surrounding communities. The *health assessment* component uses hospital and medical records, along with interview techniques to provide an analysis of the health outcomes and issues of people in the community. The information from the risk assessment and the health assessment are then combined to provide an evaluation of the potential relationships between emissions from the Upgraded IOL Refinery and the overall health of people living in the community. For further discussion on the risk assessment and health assessment methodologies, refer to Sections 4.1 and 4.2, respectively.

The PHRA was conducted using procedures developed by regulatory agencies such as Health Canada, ATSDR (Agency for Toxic Substances and Disease Registry), U.S. EPA (Environmental Protection Agency), and the Canadian Council of Ministers of the Environment (CCME). Specific steps of the risk assessment and health assessment components of the PHRA are summarized in Figure 1.


Problem Formulation
Identification of Risks and Community Health Concerns
Exposure Assessment
Toxicity Assessment
Prediction of Change in Health Impact
Risk Characterization
Evaluation of the Possible Significance of Emissions of the Upgrade to the Health of People in the Community

4.1 Health Risk Assessment Methods

An understanding of the concepts behind health risk assessments, and how the information produced can be used in the decision-making process will assist the reader in understanding this report, and in the interpretation and use of the results reported.

Risk assessments are a scientific tool which can be used to do the following:

- To help determine the major factors contributing to potential impacts on either human health or the environment;
- To evaluate the adequacy of the specific chemical entities included in the specific scenario or scenarios assessment;
- To identify whether more information or data are needed to improve the estimation of impacts, or lack thereof, from the scenarios under assessment;
- To compare the risk estimates from the scenarios assessed to those from circumstances which are more familiar to those using the report; for example, health risks associated with normal ambient background sources of substances.

The actual magnitude of the risk estimates are of secondary importance, and must be compared with some reference risk estimate, such as ambient background exposures, to be interpreted. It is important to remember the degree of conservatism in the assumptions used in risk assessments. Under most circumstances, the methods used over-estimate the degree of risks, and careful, knowledgeable and unbiased interpretation of the results is required for their use in decision-making.

Risk assessment methods have progressed significantly since their early uses in the late 1960's for the evaluation of the "safety" of pharmaceuticals and various food additives and ingredients. Major advancements have been made in the development of mathematical paradigms to evaluate the environmental fate of wide ranges of substances, and the consideration of multiple exposure pathways to estimate the total exposures of people to environmental sources of chemical substances. Another major advance was the application of various statistical approaches (*e.g.*, stochastic or probabilistic methods) in the risk assessment methodology. These techniques produce risk estimates from specific scenarios that can be subjected to sensitivity analyses to identify the relative importance of different risk factors, and enable the integration of risk estimates with other parameters and considerations (*e.g.*, engineering parameters, economics, social considerations) to provide analyses that can greatly facilitate the decision-making process.

All risk assessments require the adoption or use of various assumptions; for example:

- The specific characteristics of people / ecological receptors living in the area under assessment (*e.g.*, body weight, lifestyle factors, age distribution, current disease status);
- Features of the environment within the area under assessment (*e.g.*, rainfall, temperature,

humidity, soil characteristics, fresh and salt water features) that affect the dispersion and eventual environmental concentrations of chemicals;

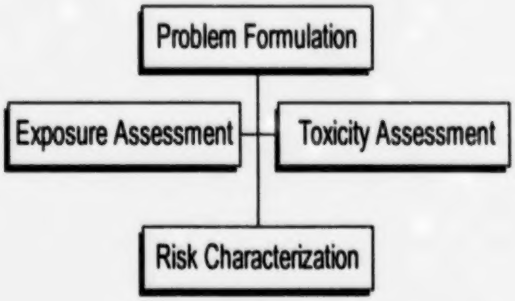
- Chemical substances of concern, and their concentrations attributable to specific sources and to the general ambient background sources.

The values used for each parameter directly affect the magnitude of the estimated risks. While actual measured site-specific data are used in risk assessment studies as much as possible, it is typical that a large number of assumptions or estimated data must also be used. For example, since the IOL Refinery Upgrade is not yet completely built and operating, data describing the future air emissions from this facility must be estimated. Typically, conservative or "reasonable worst-case" assumptions are made in the initial stages of an assessment in an effort to avoid the underestimation of risks, and to identify the components of the risk estimates that are of greatest potential concern. Therefore, an iterative (or re-assessing) approach is critical to the risk assessment process, where the risk estimates are refined using improved assumptions and new information or data specifically requested to validate assumptions made in previous risk analyses. The use of an iterative process enables the refinement of assumptions through the collection of additional or more comprehensive information based on the impact of certain assumptions on the risk estimates.

The above concepts are critical to the optimal use of the risk assessment process to achieve the most efficient and effective evaluation of potential impacts from selected scenarios, and ultimately to make the most efficient use of resources for the protection and improvement of the health of the community.

The fundamental objective of a human health risk assessment is to estimate whether people living in a given area (in this case, areas surrounding the upgraded IOL Refinery) are being exposed, or will be exposed to concentrations of chemicals that have the potential to result in adverse health effects. A human health risk assessment consists of the four main steps illustrated in Figure 2.

Figure 2 **Human Health Risk Assessment Framework**



Details of these basic steps used in the risk assessment of the IOL Refinery Upgrade are discussed in the following sections.

4.1.1 Problem Formulation

The Problem Formulation Step is an important information gathering and interpretation stage which serves to plan and focus the approach of the risk assessment. The data gathered and evaluated in this stage provides information regarding the layout of a site or facility, possible exposure pathways, identification of receptors, identification of chemicals of potential concern, and any other specific areas or issues of concern to be addressed. The key tasks in the Problem Formulation Step are discussed below, including site characterization, identification of chemicals of potential concern, receptor selection and characterization, and selection of exposure pathways and scenarios for evaluation.

4.1.1.1 Site Characterization

The site characterization phase of the risk assessment involved i) the review of available data and reports relevant to the IOL Refinery Upgrade; ii) site visits to the IOL Refinery and the surrounding communities, and iii) a series of public consultation activities (previously described in Section 3.0).

Review of Available Data and Reports

A large number of existing reports/data, peer-reviewed literature, reference materials and online data sources were reviewed in detail. In addition, personal correspondence with various experts and staff from other refinery operations was undertaken in an effort to acquire additional data or to address data gaps. Information provided to the study team by community members, such as newspaper clippings, reports, brochures, *etc.*, were also reviewed. A detailed list of all sources of data reviewed and/or contacted is provided in Appendix C.

These reports and data sources were reviewed in order to select the most appropriate data for use in the human health risk assessment. It should be noted that where data were lacking, or were insufficient to use in a quantitative risk assessment, exposures and potential health risks were assessed in a qualitative manner. In such cases, judgements have been presented with respect to the possible benefits, and thus the need, for obtaining additional data to enable the quantification of the assessment of possible health risks.

Site Visits to the IOL Refinery and Surrounding Areas

Site visits to the IOL Refinery property and surrounding areas were held in May and July of 1999. An additional site visit to areas surrounding the refinery was conducted in October, 1999. The visits were conducted to specifically examine the refinery facility and surrounding residential areas. Particular attention was given to the proximity of the areas to the refinery, and to the locations receiving the greatest emissions (*i.e.*, maximum point of impingement locations). In addition, historical data collection areas (such as soil sampling areas, *etc.*), were visited. At the time of the visits, detailed discussions with key IOL staff were conducted to gather additional information on the refinery and the upgrade project, and on the types of emissions from the refinery.

Public Consultation Activities

In order to ensure that the assessment addressed the needs and concerns of the communities surrounding the IOL Refinery, a series of public consultation activities were undertaken as discussed in Section 3.0. Through public consultation, valuable input was obtained on critical issues important to the risk assessment process.

4.1.1.2 Identification of Chemicals of Potential Concern

It is common practice in human health risk assessments to select for evaluation those chemicals which represent the greatest concern to people living in the area under consideration (*i.e.*, those with the greatest potential toxic potency and released in the greatest quantities). The concept is that examination of these chemicals of greatest concern will provide an assessment of the greatest possible health risks that could be associated with the upgraded refinery operations. If no unacceptable risk is predicted for these chemicals of greatest concern, then no unacceptable risk would be predicted for any of the chemicals which were not included in the detailed assessment. If a large degree of risk is predicted for those chemicals included in the detailed assessment, then other chemicals (from the list that was not evaluated) would be selected for further evaluation.

The identification of chemicals of potential concern in industrial emissions is based on the quantities in the emissions and their potential toxic potency. For an oil refinery, there are two main sources of emissions - stack and fugitive, which must be addressed. Fugitive emissions were restricted primarily to volatile organic compounds (VOCs). The chemicals in the stack emissions that were included, either qualitatively or quantitatively, in the evaluation included VOCs, polycyclic aromatic hydrocarbons (PAHs), metals, particulate matter (PM_{10} and $PM_{2.5}$), and combustion gases including oxides of nitrogen, oxides of sulfur, carbon monoxide, and carbon dioxide (ERA for Syncrude Upgrade, 1998; Runion, 1988; NPRI, 1999; TRI, 1999; CPPI, 1999; Weaver, 1988).

As the IOL refinery presently uses fuel gas and fuel oil as energy sources for the various refining processes, emission rates of polycyclic aromatic hydrocarbons (PAHs) and metals would be low. For fuel gas, such emissions would be particularly small. Personal communications with IOL provided information that future fuel usage will be 75% fuel gas and 25% fuel oil. Metals are more typically released from coke or Bunker C-fired facilities, and therefore are not expected to be a significant component of emissions from refinery processes fired with fuel gas or fuel oil (Dybell, 1998). Based on this information, and following confirmation with IOL regarding Bunker C fuel usage, metals were not carried forward for detailed assessment. Based on information from other refinery operations, and combustion processes generally, the burning of fuel oil (diesel) would result in a low rate of emissions of mixtures of PAHs; thus this group was selected for detailed assessment. Emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide, and particulate matter were also carried forward for detailed evaluation in the risk assessment. Although it is not an emission from the refinery *per se*, ozone was also automatically carried forward for detailed evaluation as it is a secondary reaction product that is formed in the presence of NO_x, VOCs and sunlight. Similarly, acid aerosols were also included for the detailed assessment, as they are secondary products from the reaction of sulfur and nitrogen oxides with water vapour and particulate material.

Volatile organic compounds (VOCs) from stack and fugitive emissions were also retained for evaluation. However, no data on the specific types of VOCs in stack or fugitive emissions were available from the IOL Refinery. Therefore, the specific VOCs selected for detailed assessment were based on a toxic potency screening process applied to ambient VOC data collected in the East Saint John area. It should be noted that VOCs in ambient air would represent emissions from many sources, not just the IOL refinery in isolation. Details of the VOC toxic potency screening approach are provided in Appendix D.

Three additional chemicals or chemical groups (*i.e.*, methyl-t-butyl ether (MTBE), mercaptans and reduced sulphur compounds) were identified as chemicals of potential concern and carried forward for further evaluation in the risk assessment. MTBE, mercaptans and reduced sulphur compounds are routinely found in refinery emissions.

Mercaptans are used as odourizing agents for flammable refinery products such as propane and butane fuels to enable rapid detection of leaks.

MTBE is used as an additive for unleaded gasolines to increase burning efficiency. The IOL Refinery occasionally adds MTBE to unleaded gasolines on their premises; however, if the fuel purchasers are commercial operations, MTBE is typically added to the gasoline at offsite locations (IOL, 1999e). In addition, environmental monitoring data for the Valero Refinery in Corpus Christi, Texas confirmed that refineries are a potential source of MTBE emissions.

Reduced sulphur compounds, most typically represented by hydrogen sulphide, are released during refinery processes. Since crude petroleum from different sources containing varying concentrations of sulphur, the quantities of reduced sulphur compounds released from refineries varies with the composition of the starting crude oil. Sulphur from the crude oil appears as gaseous sulphur oxides, as reduced sulphur compounds that contain hydrogen, and smaller quantities of the final refined fuels.

MTBE, mercaptans and reduced sulphur compounds are volatile organic compounds (VOCs). However, no emissions data on these substances were available for the IOL Refinery. Mercaptans had been analyzed for in recent air quality studies conducted near the refinery (Rix, 1995), but mercaptans were not detected. Since the detection limit of this study was above the odour threshold for these compounds, the data could not be used in the risk assessment. Similarly, no specific data were available on reduced sulphur compounds in the vicinity of the IOL Refinery. Therefore, mercaptans and hydrogen sulphide (a representative of reduced sulphur compounds) were evaluated in a qualitative manner for all scenarios. Potential risks related to MTBE were assessed quantitatively for the existing ambient and background scenarios (using data from other locations, since no site-specific data were available) and assessed qualitatively for the existing study area and future study area scenarios.

Table 4-1 presents a summary of all chemicals (or chemical groups) selected for evaluation in the human health risk assessment of the IOL Refinery Upgrade.

Table 4-1 Chemicals of Potential Concern for the Human Health Risk Assessment of the IOL Refinery Upgrade

Chemicals of Potential Concern				
Volatile Organic Compounds (VOCs)	**Polycyclic Aromatic Hydrocarbon Groups [1]**	**Combustion Gases**	**Particulates**	**Secondary Reaction Products**
Formaldehyde group [2, 3] Aldehyde group [2,3] Butadiene group [2] Benzene [2] Ethylbenzene [2, 4] Toluene [2, 4] Xylenes [2, 4] Methyl-tert-butyl-ether (MTBE) [2] Mercaptans [5] Hydrogen sulphide[7]	Anthracene group Benzo[a]pyrene group Fluorene group Naphthalene group	Sulphur dioxide (SO_2) [6] Nitrogen oxides (NO_x) [6] Carbon Monoxide [6]	PM_{10} [6] $PM_{2.5}$ [6] Total Suspended Particulate (TSP) [6]	acid aerosols [5] ozone [4]

[1] Individual PAHs selected for evaluation were assessed as part of these PAH groups, as per OMOE (1997).

[2] Chemical was evaluated quantitatively for the existing ambient scenario and background scenarios, however, due to a lack of data these chemicals were evaluated in a qualitative manner for the existing study area and future study area scenarios.

[3] The aldehydes were evaluated as two groups and classified according to toxicity endpoints (carcinogenicity and irritation). For more information refer to Appendix D.

[4] Ethylbenzene, toluene, and xylenes screened off in the toxic potency screening procedure but were conservatively added back to the list of chemicals of potential concern due to public concerns and the association of these chemicals with combustion and refinery processes.

[5] As no guidelines, criteria, or air concentrations were available for this chemical group, the potential for adverse health effects were evaluated qualitatively.

[6] Chemical was assessed by comparing ground level air concentrations to health-based guidelines.

[7] Hydrogen sulphide was included as a typical representative group of emissions known as reduced sulphur compounds. Due to a lack of site specific data on this chemical group, it was qualitatively evaluated in the assessment.

4.1.1.3 Receptor Selection and Characterization

A human receptor is represented as a person (*e.g.*, infant, toddler, child, adolescent, adult) who resides or works in the area being investigated and is, or could potentially be, exposed to the chemicals identified as being of potential concern. General physical and behavioural characteristics specific to the receptor type (*e.g.*, body weight, breathing rate, amount of food consumed, *etc.*) are used to determine the amount of chemical exposure received by each receptor. Due to differences in these characteristics between children and adults and between males and females, the exposures received by a female child, a male child, a female adult or a male adult will be different. Consequently, the potential risks posed by the chemicals being evaluated also will differ depending on the receptor chosen for evaluation.

Human receptors are chosen such that the most sensitive and/or most exposed individuals are represented. Consideration is given to eating habits, body surface area to weight ratios, daily activities such as the typical time spent in the work place, time spent at home either indoors or outdoors, and chemical sensitivity as a function of either physiological maturity or personal afflictions which would compromise an individuals ability to effectively cope with otherwise harmless levels of exposure. For example, small children being in a state of rapid growth and still immature in terms of development will be more sensitive than adults to chemicals in their environments. Similarly, individuals who suffer from various incurrent diseases, such as asthma, and compromised lung and circulatory function, will be particularly sensitive to exposures to chemicals that act on respiratory tissues.

As people have varying physical features, lifestyles and habits, it is not possible to evaluate all types of individuals. However, the risk assessment must be sufficiently comprehensive to ensure that those receptors with the greatest potential for exposure to chemicals of concern, and those that have the greatest sensitivity, or potential for developing adverse effects from these exposures, are included in the evaluation. With this in mind, a selection of hypothetical reasonable "worst-case" receptors, with somewhat exaggerated life style habits (to ensure a conservative assessment), were developed for consideration in the human health risk assessment.

Female receptors were selected for evaluation as they generally receive higher exposure to chemicals than males when considered on a body weight basis (*e.g.*, mg chemical/kg body weight). If no potential adverse health risks are predicted for the female receptors, then it can be assumed that less sensitive receptors receiving lower chemical exposures (*e.g.*, male receptors) also would not be at risk.

For chemicals considered to be of potential concern, a range of female hypothetical receptor types were evaluated in the existing ambient, existing study area, future study area and background scenarios, as follows:

- infant (0 to 6 months of age);
- preschool child or toddler (7 months to 4 years);
- child (5 to 11 years);
- adolescent (12 to 19 years); and
- adult (>20 years)

(Source: O'Connor Associates and Richardson, 1997).

Where possible, data gathered during the public consultation program on physical, behavioural and lifestyle characteristics of the community were used to develop exposure scenarios. Where community-specific data were inappropriate or unavailable, a series of standard human receptor characteristics and assumptions were utilized in the assessment (*i.e.*, Compendium of Canadian Human Exposure Factors for Risk Assessment; O'Connor Associates and Richardson, 1997; U.S. Environmental Protection Agency (US EPA) Exposure Factors Handbook, 1997a).

Individuals with compromised health (*e.g.*, asthmatics, chronic obstructive pulmonary disease, allergies) or within sensitive life stages (*e.g.*, pregnancy, newborn infants, children, elderly) are considered in the assessment by ensuring that selected or derived exposure limits are sufficiently stringent to protect such individuals.

It should be noted that the human health risk assessment is not based on any specific person (*i.e.*, toddler, child, adult, *etc.*) living in the vicinity of the IOL Refinery. Rather, the assessment is based on hypothetical people with composite characteristics that include those developed following discussions with residents which incorporate where possible, the physical, lifestyle and behavioural traits of people that reside in areas adjacent to the Refinery. These hypothetical people or receptors are used to provide a conservative assessment as it is based on somewhat exaggerated behavioural patterns, exposure potentials and lifestyle characteristics compared to average people in a population.

4.1.1.4 Selection of Exposure Pathways and Scenarios

People can come into contact with chemicals in their environment in a variety of ways, depending on their daily activities and the ways in which they use their land. The path a chemical travels to reach the medium (*i.e.*, air, soil, water, food, *etc.*) that a person comes into contact with are referred to as exposure pathways. The means by which a chemical moves from the medium into the body are called exposure routes. There are three major exposure routes through which chemicals can enter the body: inhalation, ingestion and dermal absorption through the skin. For each of these major exposure routes, there are a number of potential sources of chemical exposure including:

- Inhalation of air and dusts through the lungs.
- Ingestion of soils, dusts, drinking water, garden produce, food and accidental ingestion of water and sediments.
- Dermal absorption (uptake through the skin) of chemicals in air, soil, dust and water.

The potential for adverse health effects resulting from exposure to emissions associated with the IOL Refinery Upgrade are directly related to the ways in which the community becomes exposed to these chemicals (*i.e.*, the exposure pathways). If there is no possible exposure to a chemical, regardless of its toxic potency, there would be no potential for the development of adverse health effects from that chemical. Therefore, it is important to select relevant exposure pathways and routes for each receptor and scenario evaluated in the risk assessment. The selection of these exposure pathways and routes are based on site-specific data obtained during the site visit and examination of the surrounding area, as well as discussions and consultation with community members and other local stakeholders. For example, if local residents report that they grow garden produce, then consumption of homegrown produce would be selected as an exposure pathway.

Based on the available data, as well as information obtained during the site visits and public consultation, several potential exposure pathways were identified for initial evaluation in the risk assessment (see Table 4-2). These potential exposure pathways were then screened. This involved an evaluation of the relative significance of each pathway, as well as determining whether data were available to include these potential exposure pathways in a quantitative risk assessment. If data were insufficient to assess an exposure pathway quantitatively, or if a pathway was considered to be of minor significance with respect to exposure to emissions from the upgraded IOL Refinery, a qualitative assessment of the exposure pathway and resulting potential risks was conducted (See Section 5.6). Specific exposure pathways which were assessed in a quantitative manner are illustrated in the Conceptual Model (Figure 3).

Table 4-2 Exposure Pathways Selected for the Human Health Risk Assessment

Exposure Route	Specific Exposure Pathway	Evaluated or Excluded	Rationale for Evaluation / Exclusion
Inhalation through the lungs	Outdoor air	Evaluated	Chemicals in outdoor air may be inhaled into the lungs while residents living near the IOL Refinery are outdoors.
	Outdoor dust	Evaluated	Chemicals in outdoor soils may be stirred up into the air by wind action and inhaled by residents while outdoors.
	Indoor air	Evaluated	A fraction of the chemicals in outdoor air may be inhaled into the lungs while residents are indoors.
	Indoor dust	Evaluated	A fraction of the chemicals in outdoor dusts may be inhaled into the lungs while residents are indoors.
Ingestion through the mouth	Outdoor soil and dust	Evaluated	Children may incidentally ingest small quantities of soil while playing outdoors, while adults would be expected to incidentally ingest even smaller amounts of soil. Both children and adults may incidentally ingest dusts stirred up from soil while outdoors.
	Indoor soil and dust	Evaluated	A fraction of chemicals in outdoor soils and dusts may be ingested by residents while indoors.
	Drinking water	Evaluated	Chemicals in municipal drinking water supplies may be ingested by residents.
	Effluent in Little River	Excluded	Treated effluents from the upgraded refinery may be placed into Little River following treatment. These treated effluents would not represent a potential exposure pathway as the water in Little River downstream from the refinery is not potable and therefore not consumed by the community. Furthermore, Little River receives raw sewage and is subject to sea water intrusion; thus it is unlikely that it would be used as a potable water source in its current state.

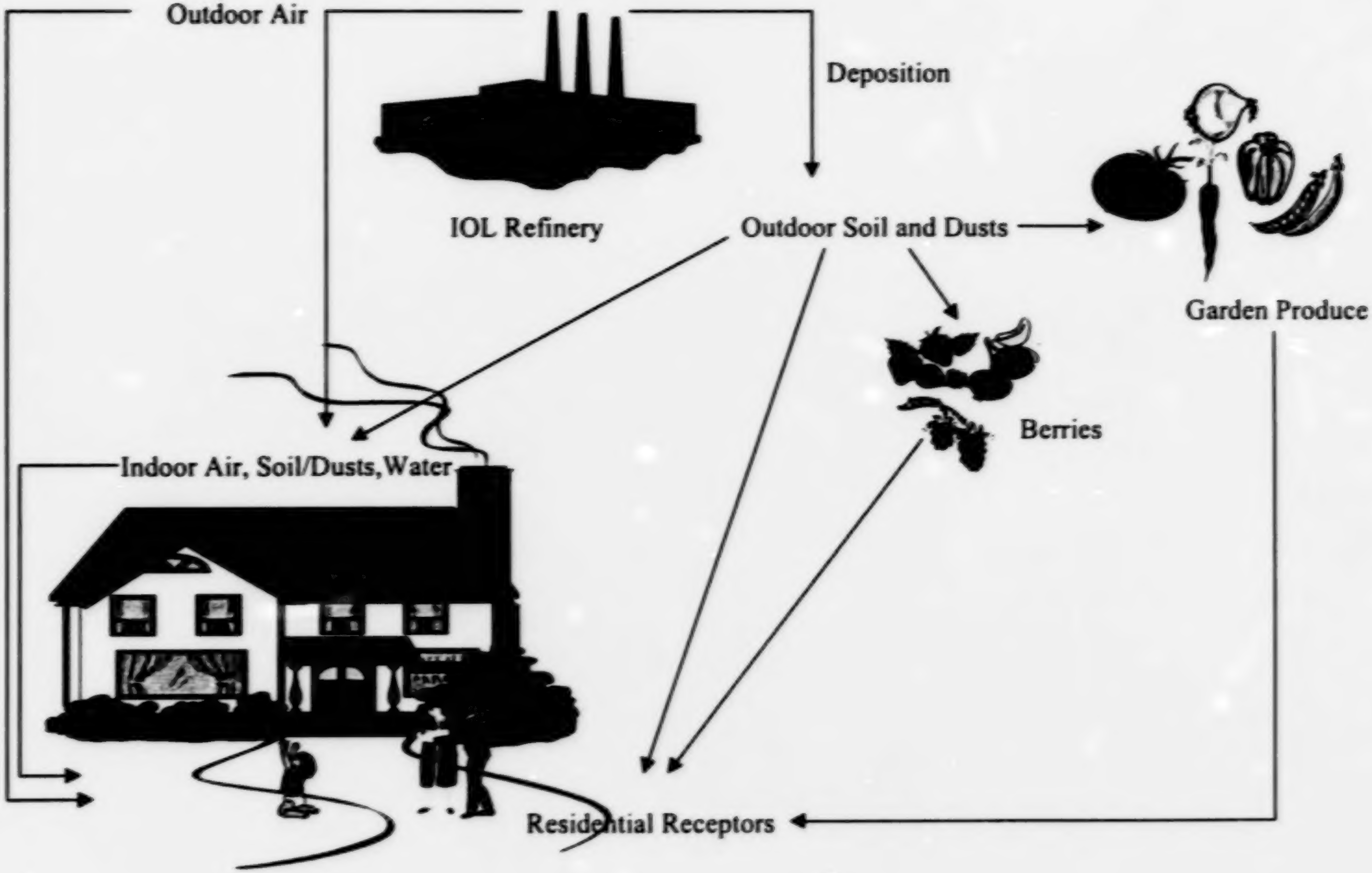
Table 4-2 Exposure Pathways Selected for the Human Health Risk Assessment

Exposure Route	Specific Exposure Pathway	Evaluated or Excluded	Rationale for Evaluation / Exclusion
	Home garden produce and berries	Evaluated	Chemicals present in soils and air may be taken up by vegetables, fruits and berries and subsequently consumed by residents. Several area residents indicated that they ate vegetables / fruits from backyard gardens and picked berries in areas surrounding the refinery. The community indicated their concern with this possible exposure pathway.
	Local game animals	Evaluated Qualitatively	Certain types of chemicals present in air, water and soils may accumulate in game animals that are hunted and eaten by community members. The community indicated their concern with this possible exposure pathway. However, as Saint John is an urban centre, hunting of game animals within city limits occurs only to a limited extent. The majority of hunting activity by Saint John residents would likely occur in areas outside the city or within less urban areas of the city that are less likely to be impacted by air emissions from the IOL Refinery. This pathway was therefore assessed in a qualitative manner.
	Fish from nearby water bodies	Evaluated Qualitatively	Certain types of chemicals present in pond water or sediments may bioaccumulate in fish and shellfish. The community indicated their concern with this possible exposure pathway. However, following a data search and correspondence with various NB DOE staff, it was apparent that there were insufficient data available for the chemicals of potential concern in local surface waters, sediments and aquatic biota. This pathway was therefore assessed in a qualitative manner.
	Swimming in nearby water bodies	Evaluated Qualitatively	Chemicals present in water and sediments may be ingested while swimming or playing in local water bodies. The community indicated their concern with this possible exposure pathway. However, following a data search and correspondence with various NB DOE staff, it was apparent that there were insufficient data available for the chemicals of potential concern in local surface waters and sediments. This pathway was therefore assessed in a qualitative manner.

Table 4-2 Exposure Pathways Selected for the Human Health Risk Assessment

Exposure Route	Specific Exposure Pathway	Evaluated or Excluded	Rationale for Evaluation / Exclusion
	Snow	Evaluated Qualitatively	Children may ingest chemicals present in snow when playing outside in the winter (*e.g.*, eating snow, chewing on gloves/mitts while playing in snow). No data were available to quantitatively evaluate this pathway; however a qualitative evaluation of the potential for adverse health effects in local children exposed for short durations to chemicals present in snow was conducted.
Dermal absorption through the skin	Outdoor soil and dust	Evaluated	Chemicals in outdoor air, soil, and dust may be absorbed through skin that is not covered by clothing.
	Indoor soil and dust	Evaluated	A fraction of the chemicals in outdoor air, soil and dust may be absorbed through skin that is not covered by clothing
	Swimming in nearby water bodies	Evaluated Qualitatively	A fraction of the chemicals in surface waters and sediments may be absorbed through the skin while swimming or playing in local water bodies. The community indicated their concern with this possible exposure pathway. However, following a data search and correspondence with various NB DOE staff, it was apparent that there was insufficient data available for the chemicals of potential concern in local surface waters and sediments. This pathway was therefore assessed in a qualitative manner.

Figure 3 Conceptual Model for the PHRA of the IOL Refinery Upgrade


Outdoor Air
Deposition
IOL Refinery
Outdoor Soil and Dusts
Garden Produce
Berries
Indoor Air, Soil/Dusts, Water
Residential Receptors

Based on information obtained during the site visits and public consultation, plus that provided by the PHRA Working Group, the following exposure scenarios were selected for quantitative evaluation in the risk assessment.

- Existing Ambient Scenario: Evaluation of the potential for adverse health effects to local residents based on calculated exposures to current measured or predicted chemical concentrations in ambient air in various areas of the communities surrounding the IOL Refinery. This scenario represents potential exposures from all emissions sources, both point and mobile (*e.g.*, industry, home heating, automobile emissions, transboundary pollution), within East Saint John. The exposure estimated for this scenario are based on analytical data of samples from ambient air monitoring stations in various locations in communities surrounding the refinery (See Appendix E).

- Existing Study Area Scenario: Evaluation of the potential for adverse health effects in local residents based on calculated exposures to predicted ground level air concentrations of chemicals, as provided by dispersion modelling of current stack emissions as defined in Stantec (1999a,b). The combined sources of emissions included were: the Irving Refinery in its present condition, Courtenay Bay Power, Irving Paper Mill, Lantic Sugar Refinery and Irving Pulp and Paper (Stantec 1999a,b).

- Future Study Area Scenario: Evaluation of the potential for adverse health effects in local residents based on calculated exposures to predicted ground level air concentrations of chemicals as provided by dispersion modelling of expected future stack emissions following the IOL Refinery Upgrade, as defined in Stantec (1999a,b). The study area included: the Irving Refinery in its upgraded condition, Courtenay Bay Power, Irving Paper Mill, Lantic Sugar Refinery and Irving Pulp and Paper (Stantec 1999a,b). The Stantec (1999a,b) modelling of future conditions assumed that there was no change in emission output for any source, other then the IOL Refinery.

- Background Scenario: All of the chemicals considered in this assessment can be found within the environment, independent of their presence in emissions from the IOL Refinery Upgrade, either from natural sources or other sources related to human activities (*e.g.*, residential heating, other industries, vehicle exhaust, long-range transport). Therefore, the background exposure scenario was based on calculated exposures of receptors to the concentrations of the selected chemicals typically found within a typical urban environment. The sole purpose of the inclusion of this background scenario was to provide a benchmark or reference, for comparison to the assessment results from the other scenarios. For the background scenario, the same receptors, exposure pathways, and parameters that were assessed in the other scenarios were evaluated. Environmental monitoring data from Fredericton, St. Andrews, Pt. Lepreau and Moncton were used in the background assessment, where appropriate and available. Where data were lacking from these locations, Halifax or other Canadian and /or American locations were used as sources of background data (See Appendix F).

- In addition to the quantitative evaluation of chemicals under the exposure scenarios listed above, qualitative assessments were conducted for the following issues that were either identified as being of concern during public consultation activities, or required as part of the terms of reference for this PHRA (See Section 5.7):

    - noise
    - potential visual effects
    - light
    - odour
    - new technologies
    - flaring
    - potential effects on surface water and well water quality
    - psycho-social / mental health effects

Following selection of the most appropriate exposure pathways and exposure scenarios for the assessment, it is necessary to determine how long human receptors may be exposed to the chemicals of potential concern through the various exposure pathways. This time will vary depending on the age of the receptor, the season of the year, and general activities of the community. Key exposure parameters and assumptions for the receptors evaluated in the risk assessment follow (refer to Appendix E for more detail):

- Receptors were assumed to be within the vicinity of the IOL Refinery 24 hours/day, 7 days/week for 365 days/year (*i.e.*, it was assumed that no one left the area, not even to go to work or to do errands, such as grocery shopping, over a 70 year period).

- The amount of time receptors were assumed to be inside and outside were obtained from the EPA's Activity Factors Handbook (US EPA, 1997) and based on discussions with the community. Child receptors were assumed to be outside for an average of 5 hours per day on weekdays and 7 hours per day on weekends, every day of the year regardless of the weather. Adult receptors were assumed to be outside for an average of approximately 2 hours per day, everyday of the year regardless of the weather. The remainder of time was assumed to be spent indoors.

- It was conservatively assumed that 30% of the total amount of root vegetables (*e.g.*, carrots, beets, potatoes), other vegetables (*e.g.*, corn, celery, lettuce), and fruits (*e.g.*, all fruits, berries and jams) consumed by residents on a yearly basis was grown in soils in areas surrounding the refinery.

- Other exposure parameters such as body weight, breathing rates, *etc.*, were taken from the Compendium of Canadian Human Exposure Factors for Risk Assessment (O'Connor Associates and Richardson, 1997).

- Meteorological data from the Saint John airport and Forest Hills monitoring station were incorporated into air dispersion modelling conducted by Stantec (1999a,b) to account for the unique weather conditions in Saint John.

Further detail on the assumptions and parameters used for the receptors, exposure scenarios, and exposure pathways evaluated in the risk assessment are provided in Appendix E.

4.1.2 Exposure Assessment

Exposure assessment involves the estimation of the rate of exposure, expressed as the amount of chemical received by individuals per unit time (*i.e.*, the quantity of chemical and the rate at which that quantity is received). Rates of exposure were calculated for all chemicals, types of human receptors, and exposure pathways selected during the problem formulation phase of the risk assessment.

The mathematical models used to estimate the rate of exposure to chemicals from the various environmental media (*i.e.*, air, soil, water) have been extensively studied and reviewed in the peer reviewed scientific literature and by various regulatory agencies. Many aspects of these mathematical models have been validated by various types of field studies. The exposure rate is typically expressed as the amount of chemical taken in per body weight per unit time (*e.g.*, µg chemical/kg body weight/day).

The degree of human exposure to chemicals in the environment depends on the interactions of a number of parameters, including:

- The concentrations of chemicals in various environmental media (*e.g.*, air, soil, food) as determined by the quantities of chemicals entering the environment from various sources, their persistence in these media (which is dependent upon the climate, depth of contamination in soil, *etc.*), and the normal ambient, or background concentrations that exist independent of a specific source. Site specific weather conditions were included in the air dispersion modelling conducted by Stantec (1999a,b) to account for the unique weather patterns in Saint John.

- The various exposure pathways and routes for the transfer of the chemicals from the different environmental media to humans (*e.g.*, inhalation of indoor and outdoor air, soil particles and dusts; ingestion of food items).

- The behavioural and lifestyle characteristics of the human receptors that determine the actual exposures through interactions with the various pathways (*e.g.*, respiration rate, water intake, food intake, soils/dusts intake, time spent at various activities and in different locations).

- The various physical, chemical and biological factors that determine the ability of human receptors to take the chemicals into their bodies via the exposure pathways and routes (*e.g.*, bioavailability of the chemicals from soil/dust particles, food, water, air).

- The physical/chemical characteristics of a chemical which determine its interaction and behaviour with its surrounding environment (*e.g.*, water solubility, volatility, tendency to bind to particles). Details of the physical and chemical parameters of chemicals evaluated in this assessment are provided in Appendix F, along with background chemical concentrations used in the assessment.

The above parameters and factors were incorporated into the computer modelling to determine potential chemical exposures for human receptors in the vicinity of the upgraded IOL Refinery. A description of the chemical data as well as the assumptions and parameters used in the exposure assessment of the existing ambient, existing study area, future study area, and background scenarios are provided in Appendices E and F.

Future exposure estimates were largely based on air dispersion analyses conducted by Stantec (1999a,b). This analysis used a computer model developed by the US Environmental Protection Agency (EPA) called the Industrial Source Complex Short Term (ISCST3) model.

Briefly, stack emission rates for particulate matter (PM) and sulphur dioxide (SO_2) were used in the ISCST3 model, along with site-specific information related to weather patterns, wind speed, topography, *etc.*, for the Saint John area. In addition, site specific information related to the IOL Refinery (such as stack heights, *etc.*) were used. The results of this computer analysis are predicted ground level air concentrations for SO_2 and PM at various locations near the refinery. These data were then used in the PHRA to estimate potential future impacts to health.

In addition to predicting future concentrations associated with the upgraded IOL Refinery, Stantec (1999a,b) also predicted current existing concentrations for SO_2 and PM. These predictions of existing concentrations can be compared against actual air data from air monitoring programs to essentially "correct" the future predictions.

The air dispersion modelling of current conditions at the IOL Refinery was conducted using current stack emission rate data for the facility (Stantec, 1999a,b). To model the future, upgraded emissions, Stantec used current stack emission rate data for existing units, and manufacturers' specified stack emission rates for new/upgraded units, which would reflect predicted or future operating conditions (Stantec, 1999a,b).

The CEI/HRMG study team used the Stantec (1999a,b) data to estimate possible future concentrations of other substances (such as PAH, NOx, CO), since future estimates for these substances were not otherwise available. The study team felt the future estimates for these additional substances were important since these compounds are typically associated with refinery emissions.

Exposure Assessment Approaches

There are two main approaches that can be used to conduct an exposure assessment. The "point estimate" or "deterministic" exposure analysis uses reasonable worst case assumptions and maximum or reasonable maximum data points, to maximize the estimate of the rate of exposure to the chemicals to ensure a conservative assessment that would not underestimate risks. In this approach, single values are used for each parameter, and risk estimates are presented as single reasonable worst case values, without any indication of variability or variance in the estimate. The deterministic approach typically results in overestimates of exposure and potential risk primarily because of the sequential combination of a large series of reasonable worst case assumptions. Consequently the deterministic risk estimates are highly conservative, and usually difficult to relate to real world situations, such as health status estimates from public health assessments.

Another approach for estimating exposure is called "probabilistic" or "stochastic" analysis. The probabilistic analysis relies on statistical procedures known as a 'monte carlo' technique. Using this approach, a range or statistical distribution of the numerical values for each parameter provide a probability distribution of the parameter values. Probabilistic exposure analysis produces more realistic risk estimates than point estimate analysis, since it calculates the range of possible exposures based on the range of values for the various parameters used in the assessment.

The assessment results using probabilistic procedures are expressed as the 5th percentile, the median (50th percentile) and the 95th percentile of the exposure distribution. The 95th percentile provides an exposure rate that would be greater than that expected for 95% of people, and represents the estimate most often used in the interpretation of the potential impacts of a particular exposure scenario.

The median value of the exposure distribution calculated using probabilistic analysis provides assessment results that can be compared to health status results developed through the public health assessment portion of the project. For the human health risk assessment of the IOL Refinery Upgrade, both the point estimate and stochastic approaches were used.

4.1.3 Toxicity (or Hazard) Assessment

Toxicity is the potential for a chemical or agent to produce any type of damage, permanent or temporary, to the structure or functioning of any part of the body. The toxicity of a chemical depends on the amount of chemical taken into the body (referred to as the "dose") and the duration of exposure (*i.e.*, the length of time the person is exposed to the chemical). For every chemical, there is a specific dose and duration of exposure necessary to produce a toxic effect in humans (this is referred to as the "dose-response relationship" of a chemical). In the toxicity assessment, information relating to the dose-response relationships of each chemical is evaluated (usually from laboratory animal studies and studies of human exposure in the workplace) in order to determine the maximum dose of chemicals to which humans can be exposed that would be associated with a very low probability of experiencing adverse health effects. These toxicity estimates are called exposure limits or reference doses, and indicate an exposure (with uncertainty spanning perhaps an order of magnitude) that is likely to be without appreciable risk or measurable adverse effects (OMOE, 1996).

Exposure limits or reference doses are generally derived for sensitive individuals using the most sensitive endpoint that has been identified. In addition, "safety" or "extrapolation" factors have been incorporated into the exposure limits by regulatory agencies to provide added protection for the population. Exposure limits are chemical-specific (*e.g.*, there are limits for benzene, and different limits for lead). For example, when studying community health issues, these same chemical-specific limits provide scientific guidance for evaluation of effects expected from different exposure conditions (*e.g.*, a study examining community exposures to benzene resulting from refinery operations would use the same exposure limits as a study examining community exposures to benzene from another industrial facility). There may be different limits for a given chemical depending upon the route of exposure, due to inherent differences in a chemicals toxicity depending upon whether it is inhaled, ingested or applied to the skin.

There are two main classes of chemicals:

- Non-Carcinogens: For the vast majority of chemicals that are non-carcinogens, scientists agree that the dose-response relationships demonstrate thresholds below which no adverse effects would be measurable or expected to occur. This threshold relationship is generally believed to hold true for all chemicals which do not cause cancer by altering genetic material (*e.g.*, most metals). Exposure limits derived for threshold-response chemicals are typically called reference doses (RfD), acceptable daily intakes (ADI) or permissible daily intakes (PDI), and are generally derived by regulatory agencies such as Health Canada and the U.S. Environmental Protection Agency (EPA). These types of limits are usually expressed as the quantity of chemical per unit body weight per unit time (*i.e.*, µg chemical/kg body weight/day). In the case of common air pollutants (which are non-carcinogens), it must be recognized that there is some debate within the scientific community with respect to whether they exhibit a threshold in their dose-response relationships. This issue does not directly affect the conclusions or interpretation of the results of the current assessment, and is discussed in greater detail in the section which follows.

- Chemicals Believed to be Potential Carcinogens: For most of these chemicals that act on the functions of genetic material and cell reproduction, it is assumed that there is no dose-response threshold. This means that any exposure greater than zero is assumed to cause some risk of development of cancer. This relationship is assumed for all chemicals which can cause cancer by damaging genetic material (*e.g.*, chemicals in the benzo[a]pyrene group, benzene). Since, in theory, any exposure to these types of chemicals has the potential to cause damage, it is necessary to define an "acceptable" degree of risk associated with these exposures. This "acceptable" degree of risk is usually defined as a risk of one-in-one hundred thousand to one-in-one-million. These numbers can be better explained as the dose rate that may cause an increased risk of mortality related to cancer in one person out of one hundred thousand people, or one person out of one million people. Exposure limits derived for chemicals believed to be potential carcinogens are typically expressed as cancer slope factors ($q1^*$) or cancer potency factors (*e.g.*, $[\mu g/kg\ body\ weight/day]^{-1}$).

The assumption of no dose-response threshold for genotoxic carcinogens ignores a large number of factors, such as the ability of the body to repair damage to genetic material, that are known to be important to the responses of people to naturally occurring genotoxic carcinogens, such as ionizing radiation striking the earth from outer space. Exposure to small concentrations of chemicals which have the potential to cause cancer happen on a daily basis to everyone in the world, because these chemicals (along with other chemicals which do not cause cancer) are present in soils, air, food and water, either from natural sources or resulting from human activities. The human body has many ways of handling these substances once they enter the body. In many cases, the body can repair damage that may be caused by exposures to low levels of carcinogenic chemicals; therefore, adverse effects do not necessarily occur.

Scientific Debate Related to Dose-Response Patterns for Common Air Pollutants

The issue of whether several common air contaminants (such as carbon monoxide, ozone, and particulate matter) exhibit a threshold in their dose-response curve is a topic of considerable scientific debate. Such a threshold would mean that no measurable adverse health effects would occur at rates of exposure less than the threshold. As such, the following section provides a brief discussion on thresholds as it relates to the human health risk assessment of air emissions.

The concept of adverse effect thresholds for responses to chemical exposures is based on a large, peer reviewed literature that demonstrates no measurable adverse responses to the chemical under examination at certain low rates of exposure. The scientific foundation for the concept of threshold is that the tissues and cells of the body have an assimilative capacity for virtually all chemicals, both of natural and anthropogenic origin. Exposures to sufficiently low quantities of such chemicals (*i.e.*, less than the assimilative capacity) does not result in adverse effects on the tissues or on the whole body.

The clearest examples of adverse effect thresholds are derived from data for various chemicals that are essential nutrients, where certain defined rates of exposure are essential for normal bodily functions and well being, yet at higher exposure rates, toxicity or adverse effects develop. Examples of such chemicals include all the essential minerals (*e.g.*, iron, magnesium, manganese, copper, zinc, sulphur, cobalt, *etc.*), various gases (*e.g.*, oxygen, carbon dioxide, nitrogen, *etc.*), and vitamins (A, D, E, B, *etc.*). All of these nutrient chemicals are toxic at elevated exposures, but essential at some lower rate of exposure. Clearly such chemicals demonstrate an exposure-response threshold, even though such a threshold may not be measurable using population-based methodologies.

Other substances that display clear thresholds are various tissue irritants, including a wide range of acids (*e.g.*, HCl, sulphuric acid, acetic acid) and various aldehydes (*e.g.*, formaldehyde, acetaldehyde). For the acids, all of which are normal endogenous (*i.e.*, present within our bodies) chemicals, the threshold for adverse effects is related to the buffering capacity of the tissues. Once the buffering capacity is exceeded, the hydrogen ions from the dissociated acids produce changes in the pH of the affected tissues. If the pH changes are great enough, tissue damage result, primarily from the denaturing of various proteins critical to cell function.

Two primary pieces of information are required in order to evaluate the existence of an exposure response threshold for a chemical: i) reliable and accurate measurements of the rate of exposure to enable identification of the dose received by the subjects under study, and ii) reliable and accurate measurements of the adverse response to the chemical. Inadequacies in such information prevent the accurate definition of the exposure threshold.

Information on adverse health outcomes associated with air pollution are derived from a large number, and various types of epidemiological studies. Such studies rely primarily on community outdoor ambient air monitoring data to derive the exposure metric in order to relate health outcome frequency with air concentrations of pollutants. As discussed in some detail in a peer panel review of these issues related to the Ontario Smog Plan (CRESTech/NERAM, 1999), community ambient air monitoring data do not provide a reliable indicator of personal exposure of people displaying adverse health outcomes because of: i) the fact that people spend greater than 80% of their time indoors; ii) many of the people displaying adverse health outcomes are hospitalized or infirm; iii) there is wide variation in the concentration of air pollutants across a given urban area, and the ambient monitoring information does not adequately represent such variability in air concentrations as received by those displaying adverse effects. Consequently, these issues related to the lack of accuracy for estimating exposures inherent in epidemiological studies of large numbers of people seriously undermine the evaluation of the exposure-response characteristics, and thus whether or not an exposure threshold exists for certain air pollutants. The difficulties in estimating exposure rates from ambient monitoring data are especially apparent at low levels of exposure where the frequency of occurrence of health outcomes decreases.

In addition, the metric (or measurement tools) used to evaluate rates of exposure raises uncertainties in evaluating exposure-response relationship in epidemiological studies (*i.e.*, studies done on humans). For example, the expression of exposures to particulate matter in terms of particle size (*e.g.*, PM_{10} and $PM_{2.5}$) and concentration in a volume of air (per cubic metre) are metrics of convenience and association and do not relate directly to adverse health outcomes. The concentration and type of particulate matter are values utilized to make an inferential conclusion about a state or condition in a population, and almost never in an individual. Most of the ambient air monitoring information on particulate matter is expressed in terms of these metrics. Adverse health outcomes, however, may be related to other metrics than particulate matter *per se*. For example, there is considerable evidence (see CRESTech/NERAM, 1999) that the acidity, SO_4 content, NO_x content, metal composition, VOC content of particulate are critical components in determining the likelihood of adverse health outcomes from exposure to particulate matter. Measurements of particle concentrations in air without coincident measures of the characteristics of the particulate matter results in considerable uncertainty in establishing associations between exposures to particulate matter and adverse health outcomes.

The precision of the metric used in endpoints of health assessment in epidemiological studies also contributes to uncertainty in the evaluation of exposure-response relationships to air pollutants. Typically the health metrics used in epidemiological studies of air pollution are hospital admissions or recruitment of mortality of people with serious cardiorespiratory illnesses. These are metrics of convenience that are used because of their ready availability; not because they are the preferred indicators of adverse health outcomes. Uncertainties arise when attempting to associate such health end point metrics to exposure parameters related to air pollution. As discussed in CREStech/NERAM (1999), a number of factors other than air pollution can result in changes in hospital admissions and recruitment of mortality of infirmed people; for example, weather patterns, changes in air temperature, humidity and indoor air quality. These uncertainties translate directly to the characterization of the exposure-response relationship, and, importantly, the uncertainties increase with decreasing exposure to air pollution and decreasing frequency of adverse health outcomes.

Reductions in the uncertainty associated with exposure- and health- outcome metrics can be achieved through the application of methods requiring individualized exposure measurements and more precise health outcome measurements. However, for practical reasons, such individual oriented studies are not always suitable for application to large populations. Delineating exposure-response characteristics for air pollutants at low exposures and low frequency of adverse health outcomes found in the vicinity of a threshold is made more difficult by the greatly reduced statistical power of such studies. As discussed in CRESTech/NERAM (1999), the evaluation of exposure-response relationships at such low exposures, based on epidemiological information, rely on mathematical models to make assumptions about the characteristics of the dose-response relationship. The basic assumption of the models used is that an exposure-response relationship is linear, and that there is no evidence of a threshold.

The assumption of a linear exposure-response relationship has been used by the U.S. EPA for decades to describe the relationships tumour formation and a chemical's potential as a carcinogen. The adoption of such an assumption for potential carcinogens was a policy decision, and was not based on definitive scientific evidence. A similar decision can be adopted for air pollutants; however, it should clearly be stated as a policy decision to enable the development of risk management decisions to improve air quality. Such a decision does not provide any insight into the actual dose-response relationship.

The data available using controlled exposure and health metric measurement demonstrate that thresholds exist for the vast majority of substances that have been tested. In addition, the available information on acid aerosols and acidic particles (*e.g.*, SO_4 particulate) demonstrate that an important part of their mode of action is as tissue irritants. For such particulate matter, mechanistic information demonstrates that exposure-response thresholds would exist (*i.e.*, no measurable responses would be observed at exposures that did not exceed the buffering capacity of exposed tissues). For other types of particulate matter (*e.g.*, $PM_{2.5}$), adverse responses appear to be related to metals or to biogenic substances and VOCs bound to particles. In such cases, it would be preferable to base the exposure criteria on metals or VOCs, thus providing an exposure metric describing the adverse health outcomes.

While it is clear that there are scientific differences of opinion on this issue, the toxicological and clinical data supports the argument for the presence of an exposure-response threshold for gaseous air pollutants. The epidemiology data clearly demonstrates rates of exposure below which no measurable or statistically significant response are evident; however, such studies are not able to identify an actual exposure threshold. This result appears due to the number of confounding exposures/issues precludes the use of these data in examining specific toxicological response patterns, in the opinion of CRESTech/NERAM (1999). Not withstanding these uncertainties, CEI has chosen to evaluate these substances using either acceptable air concentrations derived by recognized agencies such as the World Health Organization, or regulatory air quality guidelines developed by NB DOE, as benchmarks of comparison.

Selection of Exposure Limits and Air Quality Guidelines

Exposure limits are derived based on available scientific information, professional judgement and technical review by a number of experienced scientists with expertise in a wide range of scientific disciplines. In the current assessment, exposure limits for the chemicals identified as being of potential concern were identified from such regulatory sources as: Health Canada, Environment Canada, US EPA Integrated Risk Information System (IRIS) database, US EPA health assessment reports (HEAST), Ontario Ministry of the Environment, the World Health Organization (WHO), the Agency for Toxic Substances and Disease Registry (ATSDR), and the California EPA. In addition, air quality guidelines for key air pollutants were selected from either the above mentioned agencies, or NBDOE. Where more than one exposure limit or air quality guideline was available, health-based guidelines based on the most recent scientific information were chosen, since these limits are considered by many health professionals as being protective of public health.

The exposure limits used for the chemicals of potential concern via the inhalation, dermal and oral routes and the toxic endpoints on which they were based are summarized in Table 4-3. Bioavailability factors for these chemicals are also presented in Table 4-3 and are discussed later in this section. For the chemicals which were evaluated as part of a chemical group, the most conservative exposure limit identified for a member of the group (separated into carcinogenic and non-carcinogenic effects where applicable), via a particular exposure route, was selected for use in the assessment (*e.g.*, for the butadiene group, the exposure limit for 1,3-butadiene was selected to evaluate carcinogenic effects of this group via the inhalation, oral and dermal pathways; See Table 4-3).

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

Chemical + Route	Exposure Limit					Bioavailability Factor	
	Type	Value	Endpoint	Study	Agency	Route	Reference
VOLATILE ORGANIC COMPOUNDS (carcinogenic)							
Benzene							
Oral	q_1^*	0.000029 (μg/kg bw/day)$^{-1}$	leukemia (humans) (derived from inhalation exposure)	Ott *et al.*, 1978; Rinsky *et al.*, 1981; Wong *et al.*, 1983	U.S. EPA, 1999	0.97	Sabourin *et al.*, 1987
Inhalation	q_1^*	0.000025 (μg/kg bw/day)$^{-1}$	leukemia (humans)	Crump, 1992, 1994; Crump and Allen, 1984; Paustenbach *et al.*, 1993; Rinsky *et al.*, 1981, 1987; U.S. EPA ,1998	U.S. EPA, 1999	0.50-0.79	APD[c]
Dermal	q_1^*	(to be extrapolated from oral q_1^* based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
Butadiene Group [1,3-Butadiene (surrogate)]							
Oral	q_1^*	0.0006 (μg/kg bw/day)$^{-1}$	lung alveolar and bronchiolar neoplasms (female mice) (inhalation study)	Melnick *et al.*, 1990	OEHHA, 1999a	0.8	U.S. EPA, 1995
Inhalation	q_1^*	0.00085 (μg/kg bw/day)$^{-1}$	multiple tumours and tumour types (mice/rats)	NTP, 1984	U.S. EPA, 1999	0.50-0.80	APD[c]
Dermal	q_1^*	(to be extrapolated from oral q_1^* based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

	Exposure Limit					Bioavailability Factor	
Chemical + Route	**Type**	**Value**	**Endpoint**	**Study**	**Agency**	**Route**	**Reference**
Aledhyde Group [Crotonaldehyde (surrogate for oral and dermal exposure to carcinogenic aldehydes)]							
Oral	q_1^*	0.0019 $(\mu g/kg\ bw/day)^{-1}$	liver tumours (rats)	Chung *et al.*, 1986	U.S. EPA, 1997	0.5	U.S. EPA, 1995
Dermal	q_1^*	(to be extrapolated from oral q_1^* based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
VOLATILE ORGANIC COMPOUNDS (non-carcinogenic)							
Ethylbenzene							
Oral	RfD	100 μg/kg bw/day	liver and kidney toxicity (rats)	Wolf *et al.*, 1956	U.S. EPA, 1999	0.97	Sabourin *et al.* 1987
Inhalation	RfD[a]	329 μg/kg bw/day	developmental toxicity (rats/rabbits)	Andrew *et al.*, 1981; Hardin *et al.*, 1981	U.S. EPA, 1999	0.50-0.80	APD[c]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
Methyl *tert*-butyl Ether (MTBE)							
Oral	RfD	10 μg/kg bw/day	liver and kidney effects	not specified	Health Canada, 1996	0.8	U.S. EPA, 1995
Inhalation	RfD[a]	12 μg/kg bw/day	liver and kidney effects	not specified	Health Canada, 1996	0.47-0.75	APD[c]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

Chemical + Route	Exposure Limit					Bioavailability Factor	
	Type	Value	Endpoint	Study	Agency	Route	Reference
Toluene							
Oral	RfD	220 μg/kg bw/day	not specified	not specified	Health Canada, 1996	0.8	Turkall *et al.*, 1991
Inhalation	RfD[a]	1232 μg/kg bw/day	neurological symptoms and irritation of the respiratory tract (human volunteers)	Andersen *et al.*, 1983	Health Canada, 1996	0.50-0.79	APD[c]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
Xylenes							
Oral	RfD	1500 μg/kg bw/day	not specified	not specified	Health Canada, 1996	0.92	Bray *et al.*, 1949
Inhalation	RfD[a]	59 μg/kg bw/day	not specified	not specified	Health Canada, 1996	0.50-0.79	APD[c]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
POLYCYCLIC AROMATIC HYDROCARBONS (carcinogenic)							
Benzo[a]pyrene Group [IPM approach]							
Oral	q_1^{*a}	0.00018 (μg/kg bw/day)$^{-1}$	lung and stomach tumours (rodents/monkeys)	Weight-of-evidence[d]	MOE, 1997b	0.31	Rahman *et al.*, 1986
Inhalation	q_1^{*a}	0.062 (μg/kg bw/day)$^{-1}$	lung tumours (humans/rodents)	Weight-of-evidence[e]	MOE, 1997b	0.31	APD[c]
Dermal	q_1^{*a}	0.0084 (μg/kg bw/day)$^{-1}$	skin tumours (rodents)	Weight-of-evidence[f]	MOE, 1997b	0.01	U.S. EPA, 1995

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

Chemical + Route	Exposure Limit					Bioavailability Factor	
	Type	Value	Endpoint	Study	Agency	Route	Reference
Benzo[a]pyrene Group (WMM approach)							
Oral	q_1^{*a}	0.00294 (μg/kg bw/day)$^{-1}$	lung and stomach tumours (rodents/monkeys)	Weight-of-evidence[d]	MOE, 1997b	0.31	Rahman *et al.*, 1986
Inhalation	q_1^{*a}	0.98 (μg/kg bw/day)$^{-1}$	lung tumours (humans/rodents)	Weight-of-evidence[e]	MOE, 1997b	0.31	APD[c]
Dermal	q_1^{*a}	0.14 (μg/kg bw/day)$^{-1}$	skin tumours (rodents)	Weight-of-evidence[f]	MOE, 1997b	0.01	U.S. EPA, 1995
POLYAROMATIC HYDROCARBONS (non-carcinogenic)							
Anthracene Group [Anthracene (surrogate)]							
Oral	RfD	300 μg/kg bw/day	no observed effects at highest dose (mice)	U.S. EPA, 1989b	U.S. EPA, 1999	0.76	Rahman *et al.*, 1986
Inhalation	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.55-0.56	APD[c]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
Fluorene Group [Fluorene (surrogate)]							
Oral	RfD	40 μg/kg bw/day	decreased RBC, packed cell volume and hemoglobin (mice)	U.S. EPA, 1989c	U.S. EPA, 1999	0.5	U.S. EPA, 1995
Inhalation	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.43-0.44	APD[c]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

Chemical + Route	Exposure Limit					Bioavailability Factor	
	Type	Value	Endpoint	Study	Agency	Route	Reference
Naphthalene Group [Naphthalene (surrogate)]							
Oral	RfD	20 μg/kg bw/day	decreased mean terminal body weight in males (rats)	BCL, 1980	U.S. EPA, 1999	0.8	Teshima *et al.*, 1983
Inhalation	RfD[g]	0.99 μg/kg bw/day	nasal effects: hyperplasia and metaplasia in respiratory and olfactory epithelium, respectively (mice)	NTP, 1992	U.S. EPA, 1999	0.53-0.75	APD[f]
Dermal	RfD	(to be extrapolated from oral RfD based on Bioavailability Factors)[b]				0.01	U.S. EPA, 1995
GASES AND RESPIRATORY IRRITANTS (non-carcinogenic)							
Acid aerosols							
Inhalation		regulatory guideline was not available; a derived guideline is presented in Section 5.5.2.				NA[j]	
Carbon monoxide							
Inhalation	15-min RfC	100,000 $\mu g/m^3$	critical level of COHb<2.5%	Weight-of-evidence[k]	WHO, 1999	NA[j]	
Inhalation	30-min RfC	60,000 $\mu g/m^3$	critical level of COHb<2.5%	Weight-of-evidence[k]	WHO, 1999		

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

	Exposure Limit					Bioavailability Factor	
Chemical + Route	**Type**	**Value**	**Endpoint**	**Study**	**Agency**	**Route**	**Reference**
Inhalation	1-hr RfC	30,000 $\mu g/m^3$	critical level of COHb<2.5%	Weight-of-evidence[h]	WHO, 1999		
		35,000 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		
Inhalation	8-hr RfC	10,000 $\mu g/m^3$	critical level of COHb<2.5%	Weight-of-evidence[h]	WHO, 1999		
		15,000 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		
Formaldehyde (surrogate for inhalation exposure to aldehydes)							
Inhalation	1-hr RfC	60 $\mu g/m^3$	not specified	not specified	OEHHA, 1999b	NA[j]	
Inhalation	annual RfC	2 $\mu g/m^3$	upper & lower airway irritation, eye irritation (humans)	Holmstrom and Wilhelmsson, 1988; Wilhelmsson and Holmstrom, 1992	OEHHA, 1997		
Acetaldehyde (surrogate for inhalation exposure to aldehydes)							
Inhalation	annual RfC	9 $\mu g/m^3$	degeneration of olfactory epithelium (rats)	Appleman et al., 1982, 1986	U.S. EPA, 1999	NA[j]	
Nitrogen dioxide							
Inhalation	1-hr RfC	200 $\mu g/m^3$	slight changes in lung function of asthmatics (humans)	Bauer *et al.*, 1984	WHO, 1999	NA[j]	
		400 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		
Inhalation	24-hr	200 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		
Inhalation	annual RfC	40 $\mu g/m^3$	slight changes in lung function of asthmatics (humans)	Bauer *et al.*, 1984	WHO, 1999		
		100 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

Chemical + Route	Exposure Limit					Bioavailability Factor	
	Type	Value	Endpoint	Study	Agency	Route	Reference
Ozone							
Inhalation	8-hr RfC	120 $\mu g/m^3$	respiratory function responses (humans)	Weight-of-evidence[i]	WHO, 1999	NA[j]	
		127 $\mu g/m^3$ (proposed)	not specified	not specified	CWSDCPMO, 1999		
$PM_{2.5}$							
Inhalation	24-hr REL	15 $\mu g/m^3$	mortality, hospitalization, lung function, and respiratory symptoms (humans)	Weight-of-evidence[h]	HC/EC, 1999	NA[j]	
		30 or 25 $\mu g/m^3$ (proposed)	not specified	not specified	CWSDCPMO, 1999		
PM_{10}							
Inhalation	24-hr REL	25 $\mu g/m^3$	mortality and hospitalization (humans)	Weight-of-evidence[i]	HC/EC, 1999	NA[j]	
		60 or 50 $\mu g/m^3$ (proposed)	not specified	not specified	CWSDCPMO, 1999		
TSP							
Inhalation	24-hr RfC	120 $\mu g/m^3$	not specified	not specified	NB DOE, 1997	NA[j]	
Inhalation	annual RfC	70 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		
Sulphur dioxide							
Inhalation	10-min RfC	500 $\mu g/m^3$	changes in lung function in asthmatics	Lawther *et al.*, 1970	WHO, 1999	NA[j]	
Inhalation	1-hr RfC	450 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		

Table 4-3 Human Health Exposure Limits and Bioavailability Factors

	Exposure Limit					Bioavailability Factor	
Chemical + Route	**Type**	**Value**	**Endpoint**	**Study**	**Agency**	**Route**	**Reference**
Inhalation	24-hr RfC	125 $\mu g/m^3$	exacerbations of respiratory symptoms in sensitive individuals	Lawther *et al.*, 1970	WHO, 1999		
		150 $\mu g/m^3$	not specified	not specified	NB DOE, 1997		
Inhalation	annual RfC	50 $\mu g/m^3$	exacerbations of respiratory symptoms in sensitive individuals	Lunn *et al.*, 1967, 1970	WHO, 1999		
		30 $\mu g/m^3$ (specific to Saint John-Fundy ARMA)	not specified	not specified	NB DOE, 1997		

Notes: APD=airborne particle dynamics; ARMA = air resource management area; NA=not applicable; q_1*=unit cancer risk (slope factor); REL=reference exposure level; RfC=reference concentration; RfD=reference dose; TEF=toxic equivalent factor.

a Absorbed dose.
b U.S. EPA, 1989a.
c Brain and Mosier, 1980; Task Group on Lung Dynamics, 1966.
d Based on Adamson and Sieber, 1983; Dontenwill and Mohr, 1962; Homburger *et al.*, 1972; Huggins and Yang, 1962; Huggins *et al.*, 1959, 1961; Lorenz and Stewart, 1948; Neal and Rigdon, 1967; Pierce, 1961; Shay *et al.*, 1949; Stoner *et al.*, 1984; Wattenberg *et al.*, 1979
e Based on Bjørseth and Becher, 1986; Deutsch-Wenzel *et al.*, 1983; Doll *et al.*, 1965, 1972; Feron, 1972; Furst *et al.*, 1979; Grimmer *et al.*, 1984, 1987, 1988; Hammond *et al.*, 1976, 1987; Hirano *et al.*, 1974; Ishinishi *et al.*, 1976; Ketkar *et al.*, 1977; Laskin *et al.*, 1970; Lawther *et al.*, 1965; Mumford *et al.*, 1987; Nettesheim and Hammons, 1971; Saffioti *et al.*, 1972; Thyssen *et al.*, 1981; Wenzel-Hartung *et al.*, 1990; Yamamoto *et al.*, 1985
f Based on Bernfeld and Homburger, 1983; Burns, 1989; Cavalieri *et al.*, 1978, 1983; Shubik *et al.*, 1960; Takayma, 1970; Warshawsky and Barkley, 1987; Zackheim, 1964.
g RfC ($\mu g/m^3$) or Inhalation Unit Risk $(\mu g/m^3)^{-1}$ was converted to an RfD (μg/kg bw/day) or q_1* $(\mu g/\text{kg bw/day})^{-1}$7 assuming a 70 kg person breathes 23 m^3/day (Health Canada, 1994).
h Based on Burnett *et al.*, 1995; Dockery *et al.*, 1996; Raizenne *et al.*, 1996; Schwartz *et al.*, 1996.
i Based on Burnett *et al.*, 1994, 1995; Dockery *et al.*, 1992; Pope *et al.*, 1992; Schwartz, 1993, 1994; Schwartz and Morris 1995; Schwartz *et al.*, 1993, 1994, 1996.
j A bioavailability factor is not applicable since the absorbed dose is not calculated (*i.e.*, ambient air concentrations is directly compared to RfC/REL).
k Based on Anderson *et al.*, 1973; Ayres *et al.*, 1979; Beningnus *et al.*, 1977; Christensen *et al.*, 1977; Ekblom and Huot, 1972; Fodor and Winneke, 1972; Groll-Knapp *et al.*, 1972; Haider *et al.*, 1976; Horvath *et al.*, 1971, 1975; Klein *et al.*, 1980; Putz, 1979; Putz *et al.*, 1976; U.S. EPA, 1979, 1984a, 1984b; Weiser *et al.*, 1978; Winneke, 1974; Zorn *et al.*, 1986.
l Based on Folinsbee *et al.*, 1984; Horvath *et al.*, 1979; König *et al.*, 1980; McDonnell *et al.*, 1985; U.S. EPA, 1986.

Toxicity Assessment of Polycyclic Aromatic Hydrocarbons (PAHs)

A recent guidance document (*i.e.*, Scientific Criteria Document for Multimedia Standards Development Polycyclic Aromatic Hydrocarbons (PAH)) prepared by the Ontario Ministry of Environment and Energy (MOEE, 1997) was used to evaluate the toxicity of PAHs in the current assessment. Details on the application of this methodology to the evaluation of PAHs in the current assessment are provided in Appendix G. These approaches allow for the assessment of the potential additive toxicity of these substances.

Bioavailability Adjustment of Exposure Limits

The response of the body to chemicals depends on the quantity of the chemicals that gain access to the tissues and cells. Only a fraction of the chemicals ingested or inhaled or in contact with the skin are actually absorbed into the body. The fraction of the exposure received that gains access to the body is known as the bioavailable fraction.

The bioavailability of a chemical is dependent on the chemical form, the environmental medium, as well as the tissue/organ with which the chemical interacts. Thus, when applying exposure limits, it is necessary to consider the bioavailability of each chemical in the particular study from which the exposure limit is derived to obtain reasonable estimates of the quantity of the chemical entering the body. This allows for the normalization of exposures with respect to exposure route, the calculation of total exposures through all routes, and comparison of the bioavailable doses to humans with the exposure limits determined from animal studies or human epidemiological data.

The risk assessment of the IOL Refinery Upgrade was based on exposure estimates which considered the bioavailability of the chemicals of potential concern from various exposure routes. Therefore, the selected exposure limits were adjusted by multiplying the RfD or $q1^*$ by the fraction of the chemical which was bioavailable to the animals or humans in the test study on which the exposure limit was based. The rate of exposure to chemicals, as calculated for the multiple routes of exposure considered in the assessment, were also adjusted for bioavailability. Bioavailability varies between different pathways of exposure. Adjusting both the exposure limit or $q1^*$ and the calculated exposure rate for the assessment ensures that both parameters are based on the estimated dose of chemical entering the body. Further information regarding the bioavailability of the chemicals of potential concern is provided in Table 4-3.

4.1.4 Risk Characterization

The final step in the human health risk assessment component of the PHRA is the risk characterization step. The risk characterization for chemicals that are non-carcinogens consists of a comparison of the exposure limits (*i.e.*, the rate of exposure that is likely to be without measurable adverse health effects) against the total estimated exposure. This comparison is expressed as an Exposure Ratio (ER) (this ratio is referred to the US EPA as a hazard quotient or HQ) referred to and is calculated by dividing the predicted exposure by the exposure limit, as indicated in the following equation:

$$\text{Exposure Ratio} = \frac{\text{Bioavailability-Adjusted Estimated Exposure}}{\text{Bioavailability-Adjusted Exposure Limit}}$$

For irritant gases (such as sulphur dioxide, nitrogen oxides, *etc.*) and particulate matter, reference air concentrations or air quality guidelines (which are typically based on health effects data), were used as a benchmark of comparison for the measured ambient air concentrations, or predicted future air concentrations.

Risk characterization for chemicals considered to be potential carcinogens consists of a calculation of the Cancer Risk Level (CRL), which is defined as the predicted risk of an individual in a population of a given size developing cancer over a lifetime. The CRL is expressed as the prediction that 1 person per ***n*** people would develop cancer, where the magnitude of ***n*** reflects the risks to that population; for example, if the CRL is 10 persons per 100,000, the predicted risks of any individual developing cancer would be higher than if the CRL is 1 per 100,000. Generally, a level of carcinogenic risk between one-in-one million and one-in-one-hundred thousand is considered acceptable. The selection of an acceptable level of risk is a policy decision rather than a scientific decision. Based on consideration of population size, risk levels applied by other provincial jurisdictions, and the new risk-based approach which has been implemented for contaminated site assessments in Atlantic Canada (Atlantic Risk-Based Corrective Action Reference Documentation, 1999), the level of risk for this project was set at 1 in 100,000. This risk level has been accepted by the Departments of the Environment in the four Atlantic Provinces, and is currently being widely used throughout the region. The following equation provides the method whereby the CRL is calculated:

$$\text{Cancer Risk Level} = \text{Bioavailability-Adjusted Estimated Exposure} \times \text{Bioavailability-Adjusted Cancer Slope Factor}$$

ER values and CRLs are presented in the results section as both point estimate values and upper 95th percentile risk estimates, based on the point estimate (deterministic) and stochastic (probabilistic) exposure analyses, respectively. ERs and CRLs are used to express the risk of adverse health effects from exposures to the chemicals of potential concern for several reasons:

- To allow for comparisons of potential adverse health effects between chemicals and between different exposure scenarios (*e.g.*, background *versus* various site-specific conditions);
- To estimate potential adverse health effects from exposures to mixtures of chemicals that act on similar biological systems (*e.g.*, all chemicals that cause liver toxicity, or kidney toxicity, or respiratory tract cancers); and,
- To simplify the presentation of the risk assessment results so that the reader may have a clear understanding of these results, and an appreciation of their significance.

A worked example of the risk assessment calculations is provided in Appendix E.

4.1.4.1 Interpretation of Exposure Ratios and Lifetime Cancer Risk Level Estimates

For the purpose of interpreting ER's and CRL's determined in the risk assessment of the IOL Refinery Upgrade, the following criteria were used to evaluate potential health risks to humans exposed to refinery emissions.

Non-Carcinogens

- If the 95th percentile of the probabilistic assessment, or the point estimate ER value is less than 1.0, the predicted exposure rate is less than the exposure limit; therefore no measurable or observable adverse health effects would be expected for residents living within the vicinity of the refinery.

- If the 95th percentile or point estimate ER value is greater than or equal to 1.0, the predicted exposure rate exceeds the recommended exposure limit, which indicates predicted exposure could be approaching a level of concern. Prior to deciding if ER values indicate an actual level of concern requiring some type of specific action, the conservative factors and assumptions used in the assessment are reviewed. It should be noted that the exposure limits used in the assessment are primarily developed as warning signals that exposures are greater than would normally be expected or desirable. Thus, exposures at, or marginally greater than the exposure limit value do not necessarily mean that measurable increases in the incidence of adverse health effects would be expected. As previously discussed, "extrapolation factors" have been incorporated into the exposure limits, lowering the limits to values less than those generally derived for sensitive individuals and using the most sensitive adverse endpoint (Section 4.1.3). Also, since the risk assessment was conducted to indicate upper limits of exposure that residents could receive, ER values greater than 1.0 do not necessarily mean adverse health effects would be predicted for community members. Rather, for those chemicals which have ER values greater than 1.0, all assumptions and data used in the assessment were re-visited and carefully evaluated prior to making final conclusions on potential risks of adverse effects in community members.

Chemicals Considered to be Potential Carcinogens

- A predicted lifetime cancer risk level of less than 1 in 100,000 was considered acceptable.

- A predicted lifetime cancer risk level of equal to or greater than 1 in 100,000 was considered to be a potentially unacceptable level of risk, and re-evaluation was undertaken of all aspects of the assumptions made in these estimates. Similar to the discussion above for ER values for non-carcinogens, conservative factors, assumptions, and actual data used in deriving CRL's were reexamined prior to making a conclusion on whether a chemical could pose a potential for adverse health effects to members of the community.

4.1.4.2 Consideration of Chemical Mixtures

Concurrent exposures to multiple chemicals may result in interactions of these chemicals at target sites in the body. These interactions may result in a combined toxicity that is equal to the sum of the toxicities of the individual chemicals (additivity), greater than the sum (synergism or potentiation), or less than the sum (antagonism). In general, toxicological interactions of chemicals are dependent on the chemicals present, their mode of action and their environmental concentrations. Most non-additive interactions can only be demonstrated at relatively high exposures, where clear adverse effects are observed. Such interactions have not been observed or quantified at the relatively low rates of exposure typical of those associated with most environmental situations (NAS, 1983; Krewski and Thomas, 1992).

In the risk assessment of the IOL Refinery Upgrade, chemicals which were assumed to behave in an additive manner were grouped based on their relative toxic potency to the group surrogate chemical. Specific substances which included an assessment of potential additive toxicity included PAHs, aldehydes and the butadiene group.

4.2 Public Health Assessment Methods

The health assessment component of the PHRA was comprised of two main steps as follows:

- **Identification of Risks and Public Health Concerns**: This step enabled the identification of health-based questions and community concerns. It involved speaking with the community and all interested parties, and the identification of data that details community health and risk factor information. The sources of such data may be scientific studies specific to the community, hospital admission/discharge rates for the community, disease registries, *etc*.

- **Predicted Change in Public Health Impact**: This step involved a detailed assessment of current community health status by reviewing the data sources identified in the prior step. For example, this information could contain incidence rates and frequencies of hospital admissions and discharges for respiratory illnesses, emergency room visits, *etc*. Utilizing the results of the risk assessment and these data sources, statistical analyses are conducted in order to predict changes in community health impact. Particular attention was given to those public health outcomes that were considered relevant to the chemicals included in the human health risk assessment phase of the project.

Further detail of these steps are provided in Sections 4.2.1 and 4.2.2.

4.2.1 Identification of Risks and Public Health Concerns

The purpose of the public health assessment component of the PHRA is two fold:

1. To identify and summarize public health based concerns the community has from the facility now and in its upgraded form as a result of public consultation; and,

2. To identify available site-specific public health impact information of specific diseases, particularly those diseases relevant to the chemicals considered in the human health risk assessment.

Therefore, the health assessment component of the PHRA consisted primarily of identification of public health risks, community outreach, and identification of available data sources (see Sections 4.2.1.1 and 4.2.1.2). These were accessed in order to evaluate the public health status of the Saint John community at the present time. This "snapshot" of the community's health could then be used to evaluate the potential impact of the IOL Refinery Upgrade (See Section 6.0).

4.2.1.1 Public Health Risks and Community Outreach

Potential public health risks were identified using previously published scientific literature, notes from meetings with key stakeholder and community groups, and the public drop-in session.

There were a number of key stakeholder groups within the Saint John area who participated in this assessment. These groups are detailed in Section 3.0.

Following preliminary meetings with each of these groups, the types and degrees of concerns held by the group members and the community were combined with other communications received historically with respect to IOL. This information was used to develop "mental models". Mental models provide information as to the key beliefs held by the public in relation to perceived environmental health risks, in this case from the refinery upgrade, and how these beliefs are currently being addressed, and how they should be addressed in the future.

Mental models are formed from one-on-one focussed discussions with people, such as the meetings with stakeholders' groups and the drop-in session. Cognitive research has demonstrated that people's decisions and behaviours about complex issues are guided by "mental models." These models must be addressed in order to change people's behaviours, attitudes, and beliefs.

The mental model approach allows for freedom of expression and encourages elaboration on topics, and promises to reveal individual perspectives at depth. Some advantages of mental modelling include:

- Ability to clarify individual opinions and pursue their implication in depth;
- Ability to clarify questions;
- Ability to explore unanticipated topics that arise; and,
- Encourages participation and frankness through a dialogue relationship with interviewer.

Some disadvantage of mental modelling include:

- Relatively small samples size due to time limitation;
- May miss ideas that would be evoked in other settings;
- Some variability in order of discussion of issues, and depth on specific issues reflecting respondent preferences; and,
- Greater effort needed to ensure reliable data analysis.

For the public health assessment portion of this PHRA, these stakeholder meetings provided valuable insight into community health concerns such as asthma prevalence, use of inhalers "puffers", chronic respiratory disease prevalence, cancer and psycho-social effects to name just a few. Other considerations brought to light at these meetings included concerns about the impact of the refinery upgrade on leisure activities such as gardening, berry picking, and outdoor recreation (*e.g.* sports, hunting and fishing). Many of the concerns of the community centered around the psychological impact of the actual construction involved in the refinery upgrade which is not within the scope of the PHRA. However, psycho-social effects related to the upgrade were included as part of the PHRA. These concerns were evaluated for the most part qualitatively as there are no specific data available for a quantitative analysis.

4.2.1.2 Identification of Available Data Sources

The type of data obtained and source are discussed in the following paragraphs and presented in Table 4-4.

Primary Data Sources

In conjunction with the identification of community and other stakeholder concerns, a meeting and further discussions were held with the New Brunswick Department of Health and Community Services's Provincial Epidemiology Service in order to evaluate the extent of their available data. They were able to provide direct cancer incidence and mortality data for the Saint John community (including Simonds Parish) for the leading 25 cancer diagnoses. These data consisted of both incidence and incidence rates and mortality and mortality rates. The rates were calculated using the 1992 population for the same area. Fredericton was chosen as a comparison population as a result of discussions which took place in the planning stages of the assessment, and was due primarily to its proximity and available data.

A crude estimate of the prevalence of asthma inhalers or "puffers" prescribed in the Saint John area were determined by an earlier survey of participating pharmacies. The survey showed that over an 8 month time period approximately 1/3 of the Saint John population had filled a prescription for an asthma inhaler (LeBlanc J., 1999). While interesting as an anecdotal estimate, this number consists of repeat prescriptions and thus is not a true population estimate.

Secondary Data Sources

Several phone calls were made to Statistics Canada and published studies performed by Dr. Robert Beveridge of Saint John Regional Hospital were used in order to obtain data on hospital separations, emergency room visits, smoking prevalence and all other non-cancer conditions evaluated as part of Saint John's overall present public health status. The Department of Health and Community Services also provided data by way of their report entitled *Health Status of New Brunswickers, Third Report 1989-1993* (DHCS, 1995).

Table 4-4 Available Data Sources

Health Condition	NB Dept. of Health and Community Services's Provincial Epidemiology Service	Statistics Canada	*Health Status of New Brunswickers, Third Report 1989-1993.* (Region II vs. Region III)	Surveyed Participating pharmacies	Published Studies (see references)
Leading 25 cancer diagnoses (Incidence and Mortality)	XXXXXXXX				
Hospital Utilization (Hospital Care Days and Separations) for all non-cancer diagnoses			XXXXXXXX		
Smoking and other lifestyle factors		XXXXXXXX			XXXXXX
Emergency room visits					XXXXXX
Use of "puffers"				XXXXXXX	

The referent or comparison group for all of the public health status outcomes was the city of Fredericton alone (cancer) or Fredericton and the surrounding area (hospital utilization) (See map in Appendix H for definition of regions II and III). Specific data, outlining health outcome information within the East Saint John area (e.g, Forest Hills, Champlain Heights, Silver Falls, *etc.)* were incorporated where possible, but were not readily available in all cases.

4.2.2 Predicted Change in Public Health Impact

Once the current health and environmental status of the Saint John community was evaluated prior to the proposed upgrade of the IOL Refinery, the next step was to extrapolate upon that information in order to predict the potential public health impact, if any, the refinery upgrade will have on the earlier identified public health outcomes in the community. Using the common epidemiological measures known as an attributable risk (AR), attributable risk percent (AR%), and population attributable risk (PAR), it can be shown the extent to which a current particular public health outcome is a result of a specific exposure, and how this public health outcome may change as a result of changes (increase, decrease or no change) to that exposure. Thus, the attributable risk and its associated estimates can be useful as a measure of the public health impact of a particular exposure.

These predicted estimates are used to determine if any of the exposures (whether chemical or lifestyle such as smoking, *etc.*) will continue to have the greatest effect on the community of Saint John following the upgrade. It was originally proposed that logistic regression models be used to predict these exposures; however, it was determined by HRMG that more information could be gleaned from the data by evaluating each factor individually instead of by combining them into one statistical model.

5.0 HEALTH RISK ASSESSMENT RESULTS AND DISCUSSION

The quantitative results of the human health risk assessment for the IOL Refinery Upgrade are presented in Sections 5.1 to 5.5. Each of these sections focusses on a specific chemical or group of chemicals of potential concern and analyses the potential risks for each of the following scenarios:

- Existing Ambient Scenario (existing conditions in Saint John, NB);
- Background Scenario (urban areas similar to Saint John, NB, but without a petroleum refinery);
- Existing Study Area Scenario (existing conditions within the designated study area of Saint John as predicted using air dispersion modelling of major contaminant sources); and
- Future Study Area Scenario (future conditions, *i.e.*, after completion of the IOL Refinery Upgrade, within the designated study area of Saint John as predicted using air dispersion modelling of major contaminant sources).

Within this section of the report, results are presented for only the maximum point of impingement and for the most sensitive human receptor at that point, as determined by the quantification of potential risks. Potential health risks at locations other than the maximum point of impingement of emissions (*i.e.*, the point where maximum ground level concentrations of emissions would be observed) would be less. Results for these other human receptor groups and receptor locations are available and are presented in Appendix I.

For substances considered to be non-carcinogenic, the measures of potential risk were presented as exposure ratio (ER) values. These ratios were derived by dividing the predicted level of exposure by the limit of exposure defining a level of exposure that would not cause adverse health effects.

For substances considered to be potentially carcinogenic, the results were presented as incremental lifetime cancer risk levels (CRL). The incremental lifetime cancer risk levels are calculated using a composite of age classes which include a female infant, toddler, child, youth and an adult. In other words, lifetime (70 year) exposures were estimated based on the characteristics of five developmental life stages that would occur throughout a persons life. Rationale for the selection of the 70 year lifespan is provided in Appendix E, Section E.4.1.

As previously indicated, the female receptor was selected because females generally receives higher exposures to chemicals on a body weight basis than males. Therefore, if no risks are predicted for the most sensitive receptor, as determined by both exposure and potential toxicity, then it can be assumed that less sensitive receptors such as male receptors, also are not at risk.

The ER and CRL values are presented as both the 95th percentile based on the probabilistic or stochastic assessment procedures, and the worst-case point estimate based resulting from the deterministic or point estimate assessment procedures. Where sufficient data were lacking to conduct a quantitative assessment of a specific chemical group or exposure pathway, a qualitative assessment was conducted.

All of the assessment results depend on the data made available by IOL, Stantec (1999a,b) and the NB DOE, as well as that obtained from peer reviewed and other literature sources. Specific assumptions, critical to the modelling were also made based on the understanding of the issues. As a result, the assessment conclusions may change should the underlying data or assumptions change based on new information.

With respect to production rates at the IOL Refinery, the air dispersion modelling conducted by Stantec (1999a,b) was used to predict future concentrations of many substances (including SO_2, TSP, CO, NOx, PAH, *etc.*). The air dispersion study was completed using a series of data related to stack emission rates for key substances released from the refinery. The predicted ground level air concentrations used in this PHRA are based on these emission rates. Based on the nature of the upgrade, any increase in production at the refinery as a result of the upgrade is unlikely to produce a proportional increase in stack or fugitive emissions (IOL, 1999e). The basis of this statement is that the IOL Refinery is undergoing a controlled upgrade, involving the decommissioning of old stacks, thus eliminating these emission sources, and construction of new stacks, the latter being equipped with emission control technologies capable of maintaining emissions at or below those indicated by the stack parameters used in the Stantec reports (IOL, 1999e). Based on this understanding, the study team feels that the results of the risk assessment report will represent future conditions, as long as there is no significant increase in stack emission rates from those used in the air dispersion modelling. If future emission rates (following completion of the IOL Refinery Upgrade) differ significantly from those used in this report, then the findings of the risk assessment would have to be re-visited.

Qualitative assessments of the potential public health impacts due to several additional exposure pathways not considered in the quantitative assessment are presented in Section 5.6. Various comments on additional specific community concerns not included in the quantitative assessment are presented in Section 5.7.

The various assumptions used in the assessment, along with a discussion of the assessment limitations and uncertainties, are discussed in Sections 5.8 and 5.9, respectively. A brief summary of the results is presented in Section 5.10.

5.1 Polycyclic Aromatic Hydrocarbons

ER and CRL values for the existing ambient (*i.e.*, based on data from ambient air monitoring stations in the community) and background (*i.e.*, based on data from locations other than Saint John) scenarios are presented in Table 5-1 and 5-2 for non-carcinogenic PAHs and PAHs considered to have the potential to cause cancer, respectively.

Table 5-1 **Predicted ER Values for Female Receptors from Exposure to PAHs Considered Non-Carcinogenic Under the Existing Ambient and Background Scenarios**

Substance	Existing Ambient Scenario		Background Scenario	
	5th Percentile	Point Estimate	95th Percentile	Point Estimate
Anthracene	0.00000019	0.00000047	0.000022	0.000054
Fluorene	0.00039	0.00092	0.0036	0.0055
Naphthalene	0.0014	0.0013	0.0023	0.0036

Note: Results presented are for the most sensitive female receptor for the worst-case receptor location (Champlain Heights).

Table 5-2 **Predicted Female Incremental Lifetime Cancer Risk Levels from Exposure to PAHs Considered to be Potential Carcinogens Under the Existing Ambient and Background Scenarios**

Substance [1]	Existing Ambient Scenario		Background Scenario	
	95th Percentile	Point Estimate	95th Percentile	Point Estimate
Benzo[a]pyrene (group) [2] (dermal)	0.00000036	0.00000075	0.000062	0.000096
Benzo[a]pyrene (group) [2] (inhalation)	0.0000042	0.0000046	0.0000033	0.0000040
Benzo[a]pyrene (group) [2] (oral)	0.000000010	0.000000039	0.0000015	0.0000043
Benzo[a]pyrene (group) [3] (dermal)	0.0000015	0.0000033	0.000050	0.000052
Benzo[a]pyrene (group) [3] (inhalation)	0.000018	0.000019	0.0000047	0.0000057
Benzo[a]pyrene (group) [3] (oral)	0.000000042	0.00000017	0.0000013	0.0000023

Note: Shaded box indicates the lifetime cancer risk exceeded 1 per 100,000 (or 0.00001).
The incremental lifetime cancer risk levels are expressed as risk of developing cancer per 100,000 population.
Results are presented for the worst-case receptor location (*i.e.*, Champlain Heights).

[1] Results are presented for the various exposure routes as the carcinogenic endpoint for each route differed and are not considered to impact on each other.

[2] Results are presented for benzo[a]pyrene via different exposure routes for the individual PAH model (IPM). See Appendix G for more details.

[3] Results are presented for benzo[a]pyrene via different exposure routes for the whole mixture model (WMM). See Appendix G for more details.

For the existing ambient scenario, only air concentrations for the benzo[a]pyrene group (using the more conservative WMM model; see Appendix G for details), via the inhalation route of exposure, resulted in exposure rates that exceeded the risk criteria based on a one in 100,000 acceptable cancer risk level (for both point estimate and 95th percentile) (Table 5-2). However, as the exceedances over the risk criteria were marginal, and considering that the risk estimates were derived using the MOEE (1997) WMM model, which tends to overestimate risks (see Appendix G), no measurable adverse health outcomes would be expected in Saint John residents as a result of exposure to existing ambient concentrations of the benzo[a]pyrene group of PAHs.

All other PAH groups evaluated in the existing ambient scenario did not exceed the risk criteria (*i.e.*, neither the 95th percentile nor the point estimate ER values were greater than 1.0 for non-carcinogenic PAHs, and the CRL values did not exceed 1 per 100,000 for those PAHs considered to be potential carcinogens) (Table 5-1; 5-2). Therefore, no measurable adverse health outcomes would be expected from the existing ambient air concentrations of PAHs for members of the community living in the area of Saint John, NB, surrounding the IOL Refinery.

With respect to the background scenario, predicted risks for the benzo[a]pyrene group of PAHs (based on both the IPM and WMM models; see Appendix G for details, and the dermal route of exposure), were slightly elevated (*i.e.*, slightly greater than 1 per 100,000) (Table 5-2). This result has been observed in numerous other assessments. The interpretation of this result must consider the degree of conservatism known to exist in such assessment methods. This result also indicates that there are a large number of sources of PAHs related to both human activities and natural processes (*e.g.*, combustion processes, traffic, grass and forest fires, *etc.*).

To assess whether PAH emissions associated with the IOL Refinery Upgrade could have a potential impact on public health, risk levels for the existing study area and future study area scenarios were modelled and compared. The results of this comparison are presented in Tables 5-3 and 5-4 for non-carcinogenic PAHs, and those considered to have the potential to cause cancer, respectively. ER and CRL values for PAHs in the existing and future study area scenarios were calculated using the methods described in Appendix E. The methods used to estimate PAH air concentrations are also discussed in Appendix E. Briefly, the methods used to calculate ground level PAH concentrations for existing conditions used existing air monitoring data from Forest Hills (NB DOE, 1999f). To predict possible future concentrations of PAHs following completion of the upgraded refinery, the existing air monitoring data from Forest Hills were used to provide an indication of PAH groupings present, and these groupings were then applied to predicted ground level TSP concentrations, provided by Stantec (1999a) through their air dispersion modelling.

Only the location demonstrated to represent the greatest predicted air concentrations of PAHs from the areas evaluated (*i.e.*, Champlain Heights, Silver Falls, and Forest Hills) is presented in Tables 5-3 and 5-4. As indicated previously, if the potential health risks for the worse-case location (*i.e.*, maximum point of impingement) are shown to be acceptable, potential health risks at locations other than the worst case location would also be acceptable. Results for all human receptor locations and groups are presented in Appendix I.

Table 5-3 Predicted ER Values for Female Receptors from Exposure to PAHs Considered Non-Carcinogenic Under the Existing and Future Study Area Scenarios

Substance	Existing Study Area Scenario		Future Study Area Scenario	
	95th Percentile	Point Estimate	95th Percentile	Point Estimate
Anthracene	0.000000011	0.000000028	0.000000013	0.000000033
Fluorene	0.000023	0.000055	0.000027	0.000064
Naphthalene	0.000081	0.000076	0.000095	0.000089

Note: Results presented are for the most sensitive female receptor for the worst-case receptor location (Champlain Heights).

Table 5-4 Predicted Female Incremental Lifetime Cancer Risk Levels from Exposure to PAHs Considered to be Potential Carcinogens for the Existing and Future Study Area Scenarios

Substance [1]	Existing Study Area Scenario		Future Study Area Scenario	
	95th Percentile	Point Estimate	95th Percentile	Point Estimate
Benzo[a]pyrene (group) [2] (dermal)	0.000000022	0.000000045	0.000000025	0.000000052
Benzo[a]pyrene (group) [2] (inhalation)	0.00000025	0.00000028	0.00000029	0.00000032
Benzo[a]pyrene (group) [2] (oral)	0.00000000062	0.0000000023	0.00000000072	0.0000000027
Benzo[a]pyrene (group) [3] (dermal)	0.000000090	0.00000020	0.00000011	0.00000023
Benzo[a]pyrene (group) [3] (inhalation)	0.0000010	0.0000012	0.0000012	0.0000013
Benzo[a]pyrene (group) [3] (oral)	0.0000000025	0.000000010	0.0000000029	0.000000012

Incremental lifetime cancer risks are expressed as the risk of developing cancer per 100,000 population.
Results are presented for the worst-case receptor location (*i.e.*, Champlain Heights).

[1] Results are presented for the various exposure routes as the carcinogenic endpoint for each route differed and are not considered to impact on each other.

[2] Results are presented for benzo[a]pyrene via different exposure routes for the individual PAH model (IPM). See Appendix G for more details.

[3] Results are presented for benzo[a]pyrene via different exposure routes for the whole mixture model (WMM). See Appendix G for more details.

As shown in Tables 5-3 and 5-4, both the ER and CRL values for PAHs for the existing study area and the future study area scenarios were substantially less than either an ER value of 1.0, or a CRL value of 1 per 100,000. These results mean that no measurable adverse health outcomes would be expected from the concentrations of PAHs predicted in emissions.

To address the question of whether the small increases in ER values predicted between the existing and future study area scenarios are of concern relative to the range of ER values observed using the existing community ambient air monitoring data, the percentage change in the 95th percentile values between the two study area scenarios were evaluated relative to the typical range (5th to 95th percentiles) predicted for the existing ambient scenario for Saint John (see Appendix I). This comparison is presented in Table 5-5. If the predicted change in existing ambient ER values remains within the expected range (*i.e.*, the 5th to 95th percentiles predicted using the probabilistic assessment), then no changes from the existing ambient condition would be expected as a result of the IOL Refinery Upgrade. This type of evaluation is not required for the predicted CRL values, since the CRL values represent incremental risk estimates relative to those that would already exist. As the incremental CRL values are all less than 1 in 100,000, no measurable impacts on the health of the public would be expected as a result of differences between the existing and future study area scenarios.

Table 5-5 Comparison of ER Values for the Existing Study Area to Future Study Area Scenarios, and Comparison of Predicted Ambient ER Values to the Actual Ambient ER Range

Chemical	Modelled Existing Study Area 95th Percentile ER	Modelled Future Study Area 95th Percentile ER	Predicted % Change to Ambient ER	Predicted Future Ambient ER [1]	Actual Ambient ER Range (5th to 95th Percentile)
anthracene	0.000000011	0.000000013	15.4	0.000000058 [2]	0.000000014 - 0.00000019
fluorene	0.000023	0.000027	14.8	0.00016 [3]	0.000050 - 0.00039
naphthalene	0.000081	0.000095	14.7	0.00013 [4]	0.0000085 - 0.0014

[1] Predicted ambient ER value was calculated by multiplying the 50th percentile ER value for the most conservative female receptor (See Appendix I for model results) by the predicted percent change in ambient concentrations. This new value was then compared to the actual ambient ER value range currently observed.

[2] 0.000000051 (median from Appendix I) x 1.14 = 0.000000058

[3] 0.000138 (median from Appendix I) x 1.146 = 0.00016

[4] 0.00011 (median from Appendix I) x 1.144 = 0.00013

As shown in Table 5-5, predicted ambient ER values are well within the range of ER values predicted using the existing ambient community air monitoring data. Therefore, the predicted future change to PAH concentrations would not be expected to have any measurable impact on the public health of the community.

Summary

In summary, the change in risk levels predicted for PAH emissions as a result of the IOL Refinery Upgrade would not be expected to result in measurable public health impacts, relative to existing conditions.

5.2 Volatile Organic Compounds (VOCs)

The ER and CRL values for both the existing ambient (*i.e.*, based on concentrations reported for the community ambient air monitoring stations) and background (*i.e.*, based on concentrations reported for locations other than Saint John) scenarios are presented in Table 5-6 and 5-7 for non-carcinogenic VOCs, and VOCs considered to have the potential to cause cancer, respectively. Potential impacts related to mercaptans/total reduced sulphur compounds and irritant effects of aldehydes were not evaluated in a quantitative manner and are separately discussed in Sections 5.2.1 and 5.2.2, respectively. It is important to consider that the VOCs were initially screened based on detectable concentrations of these chemicals in ambient air collected at Forest Hills. The contribution of the various emissions sources considered in the existing and future study scenarios to these ambient VOC concentrations is expected to represent only a small portion of ambient concentrations based on general information that is known about the various sources of VOCs to the environment from both human activities and natural processes.

Table 5-6 **Predicted ER Values for Female Receptors for Exposure to VOCs Considered Non-Carcinogenic for the Existing Ambient and Background Scenarios**

Substance	Existing Ambient Scenario		Background Scenario	
	95th Percentile	Point Estimate	95th Percentile	Point Estimate
Ethylbenzene	0.0024	0.0071	0.00038	0.00061
MTBE [1]	1.3	2.3	0.096	0.17
Toluene	0.015	0.068	0.0012	0.0015
Xylenes	0.032	0.054	0.0039	0.0056

Note: Shaded box indicates ER value exceeded 1.0.

Results are presented for the most sensitive female receptor group.

[1] Ambient MTBE data were not available for Forest Hills in Saint John, therefore a value of 30 $\mu g/m^3$ was used. This value represents the maximum MTBE ground level air concentration measured near three refineries in the US (API, 1989). MTBE was included in the evaluation because it was a substance that was considered to be of concern by the public.

Table 5-7 **Predicted Female Incremental Lifetime Cancer Risk Levels for Exposure to VOCs Considered to be Potential Carcinogens for the Existing Ambient and Background Scenarios**

Substance	Existing Ambient Scenario		Background Scenario	
	95th Percentile	Point Estimate	95th Percentile	Point Estimate
Aldehyde group	0.000018	0.000054	NDA	NDA
Benzene	0.000025	0.0000890	0.0000050	0.0000070
Butadiene group	0.00018	0.00082	0.000046	0.000075

NDA no data available

Note: Shaded box indicates the lifetime cancer risk exceeded the acceptable level of 1 in 100,000 (or 0.00001). Incremental lifetime cancer risks are expressed as the risk of developing cancer per 100,000 population

As shown in Table 5-6, the 95th percentile and point estimate values for MTBE exceeded a value of 1.0 for the existing ambient scenario. The ER values for all other non-carcinogenic VOCs were less than 1.0. None of the non-carcinogenic VOCs had ER values greater than 1.0 in the background scenario. MTBE concentrations specific to ambient air in Saint John were not available. Therefore, for the ambient scenario a value of 30 $\mu g/m^3$ was used. This value represents the maximum MTBE ground level air concentration reported in the vicinity of three refineries in the US. Based on this conservative estimate and the conservative assumptions used in the assessment, no measurable adverse effects on the health of the public would be expected due to exposures to these air concentrations of MTBE, assuming concentrations in Saint John are similar to other areas located near refineries. However, since no data were available on MTBE air concentrations in the Saint John area, measurements of air concentrations in this area would be required to assess the validity of this conclusion.

For VOCs considered to be potential carcinogens, the predicted CRL values indicate that potential health risks would be slightly greater than the 1 in 100,000 level for the VOCs in the aldehyde group (*e.g.*, 95th percentile CRL of approximately 2 per 100,000) and benzene (*e.g.*, 95th percentile CRL of approximately 2.5 per 100,000) for the existing ambient scenario. These CRL values are marginally above the 1 in 100,000 value. No background ambient air concentration data were identified for crotonaldehyde (the surrogate for the aldehyde group) with which to compare the results for the aldehyde group. The existing ambient CRL values for benzene are only slightly greater than those in the background scenario. This is most likely due to the use of a rural background value rather than an urban background value for benzene.

The CRL values for the butadiene group also exceeded 1 in 100,000 in the existing ambient and background scenario. The exposure pathway contributing most significantly to the butadiene group CRL values was the ingestion of home garden produce. The model used to evaluate this pathway typically overestimates exposure to this chemical group. Therefore, based on the conservative assumptions used in this assessment, exposure to this chemical group would not be expected to result in adverse health outcomes. Based on other health risk assessments conducted by CANTOX ENVIRONMENTAL INC., the values presented in Table 5-7 are typical of urban environments in general, and illustrate the reason why regulatory agencies such as Environment Canada and the US Environmental Protection Agency (EPA) have focussed on VOC emission abatement programs. Since no data were available on the specific ambient sources of these substances in the Saint John area, no further comments can be made regarding the necessity for, or types of programs that could be initiated for abatement of emissions of these substances.

No data were available regarding predicted concentrations of VOCs for the existing or future study area scenarios. However, the total amount of VOCs emitted from the IOL Refinery is not predicted to change significantly as a result of the upgrade; therefore, the existing and future study area scenarios would be expected to be very similar as production rates of the IOL Refinery are not expected to change due to the upgrade. Relationships developed by the Canadian Petroleum Products Industry (CPPI) and Environment Canada (CPPI, 1988), indicate that fugitive emissions are the main sources of VOCs from refineries, and these show a strong correlation between the production volume of a refinery and the potential quantities of emissions released. IOL has indicated that the upgrade project is focussed on increased production efficiency and higher quality products, with no increase in the nameplate production volume (*i.e.*, 250,000 bbl/day). Therefore, all other factors being equal, total fugitive emissions of VOCs would not be expected to change due to the IOL Refinery Upgrade.

Current levels (1998) of fugitive VOC emissions from the IOL Refinery were available from the IOL Certificate of Approval Document and were prepared in accordance with the Fugitive Emission Leak Detection and Repair Program. These data include emissions from all accessible components including flanges, valves, pump seals, threaded connectors, and open ended lines. With respect to the IOL Upgrade, no data were available which quantified the potential change in fugitive emissions for the future scenario.

Based on the information that "leakage" of VOCs depends on the pressure maintained within the refinery processing systems, and that these pressures must be maintained irrespective of the refinery production rates, the release of VOCs would be constant within the range of production compatible with constant pressures (IOL, 1999e). This information, combined with the assumption that the IOL Refinery will continue with its Leak Detection and Repair Program (described below), would suggest that the release of VOCs via fugitive emissions is not expected to increase as a result of the IOL Upgrade.

Studies comparing different refineries indicate that fugitive emissions of VOCs have been correlated to refinery production rates (CPPI, 1988). Total hydrocarbon emission factors based on an inventory of Canadian refineries in 1988 (CPPI, 1988) were 0.05 kg/m^3 feedstock for process emissions and 0.53 kg/m^3 for fugitive process emissions. An emission factor for fugitive process emissions was also reported to be 0.25 kg/tonne of crude (0.21 kg/m^3) (CEC,1991). The USEPA suggests a value of 0.18 kg/tonne of crude but would reduce that to 0.085 kg/m^3 for a refinery with a maintenance and monitoring program (USEPA, 1985). However, these relationships are most applicable when comparing two facilities or when extrapolating from one facility to another.

When considering changes within a facility, the relationship between production rate and VOC emission rates are not expected to be valid. Increases or fluctuations in production will not necessarily be reflected by proportional changes in fugitive emissions because, within a specific refinery, pressures within the refinery system must remain relatively constant. Fugitive emissions originate from equipment leaks and are the product of imperfect tightness or failure. Leakage is function of line pressure which does not change significantly with production volumes. Consequently, within the range of production of the IOL facility (190,000 bbl to 250,000 bbl) significant changes in "leakage" of VOCs would not be expected (IOL, 1999e). Unless significant changes in production are implemented at the refinery, no resulting change in fugitive emissions would be anticipated.

The critical factor with respect to fugitive emissions of VOCs is equipment monitoring and maintenance. The leak detection and repair program at the IOL Refinery started in 1992. The purpose of the program is to detect and repair the leakage of VOC's from equipment components thus reducing overall emissions (IOL, 1999e). Sources of VOC fugitive emissions include valves, pumps, compressors, pressure relief devices, sampling systems, open-ended valves/lines, flanges, and other connectors. Oil movements were not included, as tank farms are not part of the program. Only equipment on process streams and piping are included. The results of the program indicate that in 1997, repairs lead to a 61% reduction in emissions while in 1998, the reduction was almost 30% (IOL, 1999e). Recent figures of fugitive emissions of VOCs from the refinery indicate that release rates are in the order of 100 to 150 tonnes/year. In comparison to other sources, this contribution to the air quality in Saint John is relatively small. In 1998, Irving Pulp and Paper released an estimated 211 tonnes of VOCs, while New Brunswick Power released 110 tonnes (NB DOE, 1999g). Automobiles are also a major source of VOCs and contribute significantly, releasing roughly 28 tonnes per year per 1000 vehicles (Criteria Air Contaminants Emissions for Canada, 1995). Continued efforts to reduce IOL's contribution to ambient concentrations of VOCs are to be maintained but it is apparent that significant decreases in air quality will require reduction efforts from other sectors.

5.2.1 Mercaptans / Total Reduced Sulphur Compounds

As described in Section 4.1.1.2, mercaptans and total reduced sulphur (TRS) compounds in general were identified as chemicals of potential concern and were therefore carried forward for further evaluation in the health risk assessment. Mercaptans are often categorized as total reduced sulfur compounds, which include hydrogen sulfide. These groups are discussed separately, since mercaptans are typically added to certain fuels to detect leaks, whereas hydrogen sulphide is not added, but is released during petroleum refining.

5.2.1.1 Total Reduced Sulphur Compounds (*e.g.*, Hydrogen Sulphide)

Total reduced sulphur (TRS) represents a range of sulphur containing substances, for example carbon sulphide, carbon disulphide, various catechols and hydrogen sulphide. Hydrogen sulphide is the most common of the TRS substances, and has the most toxicological and health effects data available.

TRS substances are byproducts of petroleum-based materials because of the natural sulphur content of all petroleum. The concentrations of TRS in petroleum can vary substantially depending on the area of the world where the crude petroleum originates.

This discussion of TRS substances related to the IOL Upgrade focusses on hydrogen sulphide, although it would be equally applicable to the other TRS substances.

In addition to being a byproduct of petroleum refining, hydrogen sulphide is also produced naturally in the body, primarily through naturally occurring and essential microbiological activity in the digestive tract. Between 7 and 10 litres of hydrogen sulphide is produced each day in the gastrointestinal tract of the average person (Guyton, 1981). About 0.6 litres is expelled from the body and the remainder is absorbed through the gastrointestinal tract into the body (Guyton, 1981). Once in the body, the hydrogen sulphide is metabolized and contributes to the bodies balance in sulphur metabolism (Guidotti, 1994). Sulphur is an essential component of various enzymes in the body, and is an important part of the glutathione system that functions in the excretion of various substances through the liver into the bile (Guyton, 1981).

Since hydrogen sulphide is volatile, it exists as a gas when released into the environment. This means that inhalation is the major route of external exposure to hydrogen sulphide.

The existing human data on the health effects of hydrogen sulphide (H_2S) exposure are derived primarily from uncontrolled exposure incidents and accidental acute poisonings (Guidotti, 1994). Thus, in most cases, exposure concentrations have not been accurately measured because gas clouds were accidental and transient (Glass, 1990). Nevertheless, systemic intoxication (acute central neurotoxicity) and local irritant effects (eye and respiratory irritation) resulting from H_2S exposure are well documented in the literature.

The Odour Threshold, or the minimum air concentration required for a human being to smell H_2S, is variable but very low (0.01 to 0.3 ppm, Guidotti, 1994). Concentrations of 10 ppm are allowed for 8 hour durations in occupational settings in Alberta. Up to approximately 30 ppm, H_2S smells of rotten eggs, but above 30 ppm the smell has been described as sweet or sickeningly sweet (NIOSH, 1977). Over 100 ppm people do not smell hydrogen sulphide due to fatigue and then paralysis of the olfactory nerve (Glass, 1990). The absence of smell as a warning signal at high concentrations can result in unexpected overexposure.

The Agency for Toxic Substances and Disease Registry (ATSDR) has recommended an acute minimum risk level (MRL) of 0.5 ppm for hydrogen sulphide based on respiratory effects (ATSDR, 1998).

The above summary shows that adverse health effects from hydrogen sulphide do not occur until air concentrations exceed the odour threshold by 3 to 30-fold. Early symptoms at exposures 3 to 30-fold greater than the odour threshold include nausea, tearing of the eyes and headaches (Guidotti, 1994). Since substantial quantities of hydrogen sulphide, and other TRS substances, are produced by microbial activity in the digestive tract, systemic effects from inhalation exposures in the odour range (<100 ppm) would not occur. Case studies of people exposed to levels of 10 to 20 ppm on a daily basis without demonstrating overt symptoms; and, residents of Rotorua, New Zealand who live with H_2S air concentrations ranging from < 0.005 to 1.9 ppm without evidence of adverse health effects (Siegel *et al.*, 1984). The main concern about air concentrations of TRS substances that would normally occur around a facility such as the IOL Refinery arise from the undesirable aesthetic factors associated with their pungent odour. Since there are no data quantifying actual measured concentrations of TRS compounds in the vicinity of the IOL Refinery, further assessment of this issue is not possible, but it would appear that concentrations would have to be substantially elevated before chronic health effects would be expected to occur.

5.2.1.2 Mercaptans

Mercaptans are intentionally added to odourless, flammable refinery products to enable rapid detection of accidental leaks, particularly during transportation and storage. The objectives of such uses are to avoid explosion hazards from undetected releases of such flammable products. Since no refinery emissions data or ambient air concentrations for these substances were available, mercaptans were evaluated in a qualitative manner for the PHRA.

Mercaptans may be added to refinery products on the IOL Refinery site depending on the intended use of the fuels (IOL, 1999e). For example, if the IOL Refinery products are to be purchased for commercial use, mercaptans are not typically added as commercial users of these fuel products have leak detection methods which are more sophisticated than the use of mercaptans. However, mercaptans are routinely added to fuel products that are intended for domestic use (*i.e.*, propane at service stations). It should also be noted that individual distributors and retailers of fuel products may add further amounts of mercaptans to fuels following purchase from the IOL Refinery. Although the refinery upgrade will result in the increased production of higher grade products, such as gasoline and propane, for which the addition of mercaptans may be necessary, it is expected that will be no increase in the use of mercaptans on the refinery site (IOL, 1999e). Rather, it is anticipated that the bulk of mercaptans that will be added to these fuels will be conducted by offsite domestic distributors, as typically occurs at present (IOL, 1999e).

Mercaptans are volatile, water soluble, flammable, colourless, sulfur-containing hydrocarbons with a characteristic very objectionable odour and an extremely low odour threshold. Methyl mercaptan has an odour described as that of rotten cabbage (ACGIH, 1997), and ethyl mercaptan has one of the most penetrating, persistent and objectionable leek-like odours known (ACGIH, 1997). Other mercaptans, such as butyl mercaptan have similar objectionable odours, and as a group their odours resemble that of hydrogen sulfide (rotten egg gas), although mercaptan odours can be detected at much lower air concentrations (ACGIH, 1997). In fact, the concentrations that human olfactory senses can detect mercaptans (odour thresholds) are substantially less than their analytical detection limits using sophisticated chemical analysis equipment. Mercaptans are produced chemically by reactions of various hydrocarbons (methane, ethane, butane, *etc.*) with hydrogen sulfide.

The available scientific information demonstrates that mercaptans act on the human body in a manner similar to hydrogen sulfide, namely, exposures to high concentrations depresses the respiratory centres of the central nervous system. Effects observed over longer term exposures conducted with animals appear to be mainly the result of general discomfort due to the potent odours of these chemicals, resulting in stress, decreased food consumption (related to the animals attempting to avoid the odours) and a variety of secondary, indirect effects.

An odour recognition threshold of 0.004 mg/m^3, an odour detection threshold of 0.00001 to 0.0004 mg/m^3 and a taste detection threshold of 0.002 mg/m^3 have been reported for methyl mercaptan (Stahl, 1973). Amoore and Hautala (1983) reported an odour threshold for methyl mercaptan of 0.0032 mg/m^3.

Accidental exposure of 28 students to 8 mg/m^3 methyl mercaptan (or concentrations 2500-fold greater than the largest odour detection threshold reported) resulted in headaches and nausea (Sandmeyer, 1981). Of the 28 students, 27 recovered within 24 hours of removal from the contaminated area. One student showed signs of liver effects, which normalized within 6 weeks.

The available epidemiology studies demonstrate a relationship between exposure to mixtures of reduced sulphur compounds (*e.g.*, various mercaptans, dimethyl sulphide, dimethyl disulphide, hydrogen sulfide) and lung and eye irritation effects, lung and kidney tissue injury, and perturbations in haematology parameters and iron metabolism (Shultz *et al.*, 1970; Tenhunen *et al.*, 1983; Klingberg *et al.*, 1988; Klingberg *et al.*, 1988). With the exception of perturbations in iron metabolism, all of these effects have also been observed in laboratory animals exposed to reduced sulphur compounds. However, the lack of information on the magnitude of exposure in most human studies precludes the assessment of dose-response relationships and therefore the quantification of potential health risks from exposure to reduced sulphur compounds. In addition, the presence of other chemicals which may induce similar effects were not accounted for in the majority of these studies, thus preventing any definitive conclusions regarding an association between the observed health effects and exposure to reduced sulphur compounds.

The lowest no-observable-adverse-effect (NOAEL) concentration identified from the available chronic or subchronic inhalation studies is 34 mg/m^3 of methyl mercaptan (Tansy *et al.*, 1981). This value was based on a subchronic 90 day laboratory study with rats. The lowest no-observable-adverse-effect concentration identified from the available acute inhalation studies is 1000 mg/m^3 of methyl mercaptan (Ljunggren and Norberg, 1943). In this laboratory study, no effects were observed in rats exposed for 30 minutes to air concentrations of 1000 mg/m^3 of methyl mercaptan. It should be noted that this air concentration is greater than 9000-fold above the odour threshold. Therefore, the use of conventional methodology (*e.g.*, application of 100-fold or larger extrapolation factors to the NOAEL) to arrive at a "safe" air concentration for chronic (life time) continuous exposure of the general population is a relatively meaningless exercise with no practical application. The data clearly demonstrate that no adverse health consequences would occur unless air concentrations were many fold greater than the odour detection threshold, a situation which people would definitely avoid because of the highly objectionable odour that would be experienced at such air concentrations.

While odours from the refinery have been identified as a cause of public concern (See Section 5.7.4), there are presently no data available which would indicate the degree to which mercaptans contributed to these odours. Murphy *et al.*, (1996) and Rix (1995) reported that mercaptan compounds were non-detectable in an eight month investigation of odours associated with the IOL Refinery. However, since the detection limits for mercaptans were above their odour thresholds, their contribution to objectionable odours in the vicinity of the IOL Refinery could not be ruled out (Murphy *et al.*, 1996; Rix, 1995). Both studies concluded that further analysis was required.

Based on the information available as summarized above, it is unlikely that existing mercaptan air concentrations would pose a health concern to nearby residents. However, due to the low odour thresholds for these compounds, there remains a potential for objectionable odours, not associated with adverse health consequences, that may adversely impact aesthetic conditions for local residents. Based on a review of the IOL Application document (IOL, 1998), and subsequent discussions with IOL representatives, there do not appear to be any aspects of the refinery upgrade project that would likely result in the increased use, and subsequent emissions of mercaptan compounds beyond present levels. While the production of propane and butane will increase, it is our understanding that the bulk of these products will be sold to distributors without additional mercaptans being added. Therefore, no significant change in mercaptan air concentrations would be expected as a result of the IOL Refinery Upgrade.

5.2.2 Irritant Effects of Aldehydes

Guidelines

To assess the irritation effects of aldehydes in the ambient air, total aldehyde concentrations were compared to the 1-hr guideline of 60 $\mu g/m^3$ for formaldehyde and annual guideline of 9 $\mu g/m^3$ (US EPA, 1999). A 24-hour guideline was not available, however, a range can be estimated by assuming it is 3- to5-fold lower than the 1-hour guideline.

Background Concentrations

Of the aldehydes, data on background concentrations for acetaldehyde, acrolein and formaldehyde were identified. No New Brunswick or Canadian background concentrations were identified in the literature reviewed, therefore US data are presented. In 1989, mean air concentrations of acetaldehyde in 14 study areas in the United States was 2.5 $\mu g/m^3$ (ARB, 1997). Median daily concentrations of formaldehyde were 4.67 to 8.12 $\mu g/m^3$ in four cities in New Jersey in the late 1970's (Cleveland et al., 1977). In 1976, minimum, mean and maximum air concentrations of acrolein in Edison, New Jersey were 0.4, 0.7 and 1$\mu g/m^3$ (Brodzinsky and Singh, 1982). A sum of these three aldehydes is at least 7.57 $\mu g/m^3$ (2.5$\mu g/m^3$ + 4.67 $\mu g/m^3$ + 0.4 $\mu g/m^3$), which would not account for all the aldehydes present in the air. The available information indicates that background sources of these substances range from natural releases from growing plants (especially evergreens such as pines), decaying vegetation, wood burning, automobile emissions and a wide range of industrial processes (*e.g.*, processing coffee, paints, manufacturing vinyl products). Data from the United States on source apportionment indicates that wood burning accounts for over 80% of the total environmental load of acetaldehyde (IARC, 1985).

Existing Ambient Concentrations in Saint John

Data for ambient levels of acrolein and formaldehyde in Saint John were available for Forest Hills from 1996-1998 (NB DOE, 1999f). The 95th percentiles of acetaldehyde, acrolein and formaldehyde in Saint John are lower than the "background" air concentrations identified in the U.S. The sum of the 95th percentile 24-hr concentrations of total aldehyde in Saint John are approximately 6.28 µg/m^3 based on the data reported between 1996 and 1998 (Table 5-8). This 24-hr total value would be multiplied by a factor of between approximately 3 to 5 to provide an estimate of the 1-hr average air concentration; resulting in an estimated 1-hr 95th value for total aldehydes between 19 and 32 µg/m^3. This estimated 1-hr value is less than the 1-hr guideline for formaldehyde (60 µg/m^3; BCMELP, 1995). The sum of the average 24-hr concentrations is 3.44 µg/m^3, or about 3-fold less than the annual guideline for acetaldehyde (9 µg/m^3; refer to Table 5-8). These short-term ambient guidelines are established considering people who have medical conditions that are known to increase their sensitivity to respiratory irritants (*e.g.*, people with asthma). Therefore, current levels of aldehydes in the air would not be expected to cause respiratory irritation to the general public.

Table 5-8 Comparison of 24-Hour Aldehyde Ambient Concentrations in Saint John to Guidelines

Aldehyde in Saint John Ambient Air	Maximum (µg/m^3) (24 hour)	95th Percentile (µg/m^3) (24 hour)	Mean (µg/m^3) (24 hour)
Acetaldehyde	6.19	2.299	1.102
Acrolein	0.688	0.179	0.088
Benzaldehyde	0.488	0.274	0.12
Crotonaldehyde	0.281	0.233	0.088
Formaldehyde	5.138	2.485	1.27
Hexanal	0.456	0.288	0.103
Isovaleraldehyde	0.441	0.314	0.131
Propionaldehyde	1.328	0.73	0.315
m-Tolualdehyde	0.178	0.12	0.061
p-Tolualdehyde	0.085	0.05	0.05
Valeraldehyde	0.518	0.282	0.116
TOTAL	**14.75**	**6.28**	**3.44**
Guidelines	1-hr averaging time: **60 µg/m^3** (BCMELP, 1995) (ambient air action level for formaldehyde)	24-hr averaging time: **12-20 µg/m^3** (estimated) (estimated assuming the 24-hr averaging time is 3- to 5-fold lower than the 1-hr averaging time)	annual averaging time: **9 µg/m^3** (U.S. EPA, 1999) (RfC for acetaldehyde)

Source of ambient air data: NB DOE. 1999f.

Existing and Future Study Area Concentrations

No data were available to enable air dispersion modelling of aldhydes for the existing and future study area scenarios. However, based on the information reviewed, refineries do not appear to be a major source of aldehydes in the environment (IARC, 1985). Therefore, the IOL Refinery would not be expected to contribute significantly to the concentrations of aldehydes measured in the community ambient air monitoring stations. In addition, the IOL Refinery Upgrade would not be expected to change this situation in the future. This evaluation indicates it is unlikely that any change in air concentrations of this class of VOCs resulting from the upgrade would have measurable impacts on the public health of the community. However, since no data were available on aldehyde concentrations in emissions for the existing and future study area scenarios, measurements of air concentrations in these emissions would be required to assess the validity of this evaluation.

5.3 Combustion Gases

Combustion sources produce a number gaseous air pollutants. Of these, oxides of sulfur (SOx), oxides of nitrogen (NOx), and carbon monoxide (CO) are considered "criteria pollutants". Activities at the IOL Refinery contribute to the existing air quality in Saint John , NB and the refinery upgrade will potentially change this contribution with respect to SOx, NOx and CO. The potential impact of combustion gases, related to the IOL Refinery Upgrade, was evaluated by comparing existing ambient and predicted future concentrations to other urban background and guideline values. Results for SOx, NOx and CO are presented in Sections 5.3.1, 5.3.2 and 5.3.3, respectively.

5.3.1 Sulphur Dioxide

Sulfur dioxide (SO_2) is a product of combustion of sulfur containing fossil fuels such as coal, fuel oils and gasoline. This heavy, colourless gas combines readily with water vapour, forming aerosols of sulfurous acid, a mildly corrosive liquid. Further reaction with oxygen forms sulfuric acid, which is a corrosive agent and a tissue irritant.

Health effects associated with SO_2 exposure are primarily related to irritation of the respiratory system. These tissue irritant effects occur when the acid buffering capacity of the tissues of the respiratory system are exceeded. The elderly, those with chronic lung disease, and asthmatics are especially susceptible to such effects. Short-term exposure to air concentrations of SO_2 greater than approximately 1500 $\mu g/m^3$ may cause irritation of the upper respiratory tract and lung in people without predisposing health conditions. In sensitive individuals, such as asthmatics, these effects are observed following short-term exposure (a few minutes) to air concentrations of SO_2 as low as 750 $\mu g/m^3$ (WHO, 1999). These effects can lead to chronic coughing, difficulty breathing. Chronic exposures to air concentrations of SO_2 that cause irritant effects may be associated with an increased incidence of respiratory tract infections (WHO, 1999).

Guidelines

Maximum permissible concentrations of ground level concentrations of sulphur dioxide (SO_2) in Saint John are summarized in Table 5-9. These objectives have been adopted as exposure criteria for the assessment of SO_2 emissions from the IOL Refinery. Guidelines for levels of SO_2 in ambient air were also available from the WHO (1999). A 10-minute average air guideline was set at 500 $\mu g/m^3$ which is specifically aimed at the protection of people with medical conditions that would be exacerbated by SO_2 such as those with asthma and other respiratory conditions (WHO, 1999). The 1-hr average Air Quality Objective is 450 $\mu g/m^3$ (NB DOE, 1997). The WHO 24-hr guideline is less than the corresponding NB DOE guideline for Saint John (125 versus 150 $\mu g/m^3$); whereas the WHO annual guideline is greater than NB DOE's guideline for Saint John (50 versus 30 $\mu g/m^3$).

Background Concentrations

Background data (see Table 5-9) for five maritime cities, other than Saint John, were obtained from the National Air Pollution Surveillance (NAPS) Network Annual Summary for 1994 and 1997, which was compiled by Environment Canada (1997; 1999). Air data were available from monitors at four commercial locations (254 Water Street, St. John's; 56 Fitzroy Street, Charlottetown; 1657 Barrington Street, Halifax; and County Jail, Sydney); one industrial location in CFB Shearwater, Halifax; and one residential location on South Street, Glace Bay. The air quality in these maritime cities was used as a relative comparison with that in Saint John.

When considering the air monitoring data for both 1994 and 1997, the 95th percentile concentration of the 1-hour averaging times ranged from 11 ug/m^3 to as much as 86 ug/m^3. When averaged over 24-hours, the 95th percentile concentration ranged from 10 ug/m^3 to 60 ug/m^3. Annual averages ranged from 2.6 to 31 ug/m^3. In each case, the lowest SO_2 levels were recorded in Charlottetown, PEI, while the highest were in Halifax, Nova Scotia.

Existing Ambient Concentrations in Saint John

Data for ambient concentrations of SO_2 in Saint John (see Table 5-9) were available at six community ambient air monitoring locations: Forest Hills (1994-1997); 189 Prince William (1994 and 1997); Forest Products (1996-1998); Silver Falls (1996-1998); Three Mile (1996-1998); and Champlain Heights (1996-1998). Although data are available from previous years, the most recent data were used in order to more accurately represent current trends in air quality.

For the Saint John monitoring stations, including only Forest Hills and Prince William, between 1994 to1998, the 95th percentile air concentration of SO_2 based on 1-hour averaging times ranged from 50 ug/m^3 to 113 ug/m^3. When averaged over 24-hours, the 95th percentile concentration ranged from 37 ug/m^3 to 84 ug/m^3.

In 1998, additional data were available from monitors in Silver Falls, Champlain Heights, Forest Products, and at Three Mile. The 95th percentiles were not reported but monthly peaks concentrations based on hourly measures ranged from 92 ug/m^3 at Three Mile to as high as 1051 ug/m^3 at Forest Products.

Annual averages for all of the monitoring stations ranged from 8 to 26 ug/m^3. Some of the highest concentrations of SO_2 were found at the Forest Products monitoring station and the stations at Silver Falls and Champlain Heights.

Comparison of Existing Ambient Concentrations to Urban Background and Guideline Values

Ambient concentrations (95th percentiles and annual averages) of SO_2 in Saint John are similar to the background values reported for other maritime cities (Table 5-9). The NB DOE reported that air concentrations of SO_2 exceeded the 1-hour and/or 24-hour guidelines at some of the monitoring stations in Saint John during 1996 and 1997, including Forest Hills, Champlain Heights and Silver Falls (NB DOE, 1999b). For Forest Hills, the exceedances are outside the 95th percentiles, indicating that they represent individual data point exceedances that occurred infrequently (*i.e.*, less than 5% of the time). These exceedances are such that sensitive members of the community (*i.e.*, those with asthma or other respiratory conditions) would potentially experience acute or short-term respiratory responses (*e.g.*, coughing, irritation, short-term decreased lung function) if they were at the locations when these exceedances occurred. However, such responses, would not be expected to cause chronic health outcomes.

Comparisons could not be made for monthly means or monthly maximum values as no guidelines were available for these durations of time. The annual means were below the annual average time guidelines.

Table 5-9 Comparison of SO_2 Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
1-hr averaging time			
Forest Hills	1994 50th percentile: 5.2 $\mu g/m^3$ 1994 95th percentile: 113 $\mu g/m^3$ 1997 95th percentile: 112 $\mu g/m^3$	commercial: 254 Water Street, St. John's 1994: 95th percentile: 34 $\mu g/m^3$ 1997: 95th percentile: 31 $\mu g/m^3$ commercial: 56 Fitzroy St., Charlottetown 1994: 95th percentile: 13 $\mu g/m^3$ 1997: 95th percentile: 11 $\mu g/m^3$ industrial: CFB Shearwater, Halifax 1994: 95th percentile: 86 $\mu g/m^3$ commercial: 1657 Barrington St., Halifax 1994: 95th percentile: 81 $\mu g/m^3$ commercial: County Jail, Sydney 1994: 95th percentile: 34 $\mu g/m^3$ residential: South St., Glace Bay 1994: 95th percentile: 55 $\mu g/m^3$	450 $\mu g/m^3$ (NB DOE, 1997)[2] (1 hour average) 500 $\mu g/m^3$ (WHO, 1999) (10 minute average)
189 Prince William	1994 50th percentile: 5.2 $\mu g/m^3$ 1994 95th percentile: 58 $\mu g/m^3$ 1997 95th percentile: 50 $\mu g/m^3$		

Table 5-9 Comparison of SO_2 Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
24-hr averaging time			
Forest Hills	1994 50th percentile: 10 $\mu g/m^3$ 1994 95th percentile: 84 $\mu g/m^3$ 1997 95th percentile: 83 $\mu g/m^3$	commercial: 254 Water Street, St. John's 1994: 95th percentile: 26 $\mu g/m^3$ 1997: 95th percentile: 24 $\mu g/m^3$ commercial: 56 Fitzroy St., Charlottetown 1994: 95th percentile: 10 $\mu g/m^3$ 1997: 95th percentile: 11 $\mu g/m^3$ industrial: CFB Shearwater, Halifax 1994: 95th percentile: 58 $\mu g/m^3$ commercial: 1657 Barrington St., Halifax 1994: 95th percentile: 60 $\mu g/m^3$ commercial: County Jail, Sydney 1994: 95th percentile: 31 $\mu g/m^3$ residential: South St., Glace Bay 1994: 95th percentile: 52 $\mu g/m^3$	125 $\mu g/m^3$ (WHO, 1999) (24 hour average) 150 $\mu g/m^3$ (NB DOE, 1997) [2] (24 hour average)
Silver Falls [1]	1998 monthly means: 5.2-31 $\mu g/m^3$ 1998 monthly 1 hr maximums: 162-479 $\mu g/m^3$		
Champlain Heights [1]	1998 monthly means: 7.9-18 $\mu g/m^3$ 1998 monthly 1 hr maximums: 157-569 $\mu g/m^3$		
Forest Products [1]	1998 monthly means: 5.2-55 $\mu g/m^3$ 1998 monthly 1 hr maximums: 139-1051 $\mu g/m^3$		
Three Mile [1]	1998 monthly means: 2.6-16 $\mu g/m^3$ 1998 monthly 1 hr maximums: 92-207 $\mu g/m^3$		
189 Prince William	1994 50th percentile: 10 $\mu g/m^3$ 1994 95th percentile: 42 $\mu g/m^3$ 1997 95th percentile: 37 $\mu g/m^3$		

Table 5-9 Comparison of SO_2 Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
Annual averaging time			
Forest Hills	1996 mean ± SD: 18 ± 37 μg/m³ 1997 mean ± SD: 21 ± 45 μg/m³	1994: commercial: 254 Water Street, St. John's mean ± SD: 10 ± 13 μg/m³ 1994: commercial: 56 Fitzroy St., Charlottetown mean ± SD: 2.6 ± 5.2 μg/m³ 1994: industrial: CFB Shearwater, Halifax mean ± SD: 21 ± 31 μg/m³ 1994: commercial: 1657 Barrington St., Halifax mean ± SD: 31 ± 26 μg/m³ 1994: residential: South St., Glace Bay mean ± SD: 21 ± 26 μg/m³	50 μg/m³ (WHO, 1999) (annual average) 30 μg/m³ (NB DOE, 1997) (annual average) [2]
Silver Falls	1998 mean: 18 μg/m³		
Champlain Heights	1998 mean: 13 μg/m³		
Forest Products	1998 mean: 26 μg/m³		
Three Mile	1998 mean: 8 μg/m³		
189 Prince William	1994 mean ± SD: 13 ± 26 μg/m³ 1997 mean ± SD: 13 ± 21 μg/m³		

[1] Monthly means and monthly maximum values are not comparable to the 24-hour average time guidelines, but are included in this table for the information of the reader.

[2] Maximum permissible ground level concentrations of SO_2 in the counties of Charlotte, Kings and Saint John, are half the value of the SO_2 guidelines set for the rest of the Province of NB (NB DOE, 1997). As the IOL Refinery is located in Saint John county, the guidelines cited for this area were used in the PHRA.

Existing and Future Study Area Concentrations

Predicted ground level air concentrations of SO_2 for the study area, under existing and future conditions, were estimated using air dispersion modelling (Stantec, 1999b). The sources of SO_2 emissions considered included the combined stack emissions from the IOL Refinery, Courtenay Bay Power Plant (CB), and the Irving Paper Mill (IP). These emissions data were available for both the current and future scenarios. Stack emissions of SO_2 under the current scenario were based on existing stack emissions data available for the facilities of interest. With respect to the IOL facility, the stack emissions data reflects an average production rate of approximately 190,000 bbl/day. The stack emissions from the IOL facility for the future scenario were obtained by subtracting the contribution from units that were going to be removed as a result of the upgrade and subsequently adding the predicted emissions from those units that were being constructed. Estimations of stack emissions for the new units were obtained from the operating specifications supplied by the equipment manufacturer and thus represent optimum conditions.

The contribution of SO_2 from Courtenay Bay Power Plant, and the Irving Paper Mill were assumed to remain constant between the exiting and future scenarios. Wind speeds and direction, precipitation and other local weather conditions were considered using one year of meteorological data which spanned from 1997-1998 (Stantec, 1999b).

As discussed, the IOL upgrade will involve the decommissioning of specific units as well as the construction of new ones. The result, with respect to SO_2 emissions, will be a net decrease of roughly 29% in SO_2 emissions compared to current, existing conditions. When considered together with the SO_2 contributions from CB and IP, the overall predicted decrease in SO_2 emission rates from the industrial complexes in the region is approximately 18%.

Predicted air quality data were summarized for three locations within the study area: Forest Hills, Silver Falls, and Champlain Heights (See Table 5-10). A comparison of the modelled daily ground level air concentrations of SO_2 at Forest Hills showed an average decrease of 4.9 ug/m^3 (95% CI of 0.97) over the 364 days modelled. In relation to the modelled existing mean SO_2 concentrations, at this location (102.95 ug/m^3 with a 95% CI of 48.77), there was a predicted decrease of between 4% and 6% following the IOL Upgrade. The modelled data for Silver Falls and Champlain Heights demonstrated similar trends with decreases in ground level SO_2 concentrations following the IOL Upgrade ranging from 5 to 8% for Silver Falls and 7 to 10 % for Champlain Heights.

The potential change in the ground level air concentrations of SO_2 described above as the percent difference between the annual means is discussed for the sake of convention, and does not reflect the predicted maximum or minimum values provided by the model predictions. The data sets produced by the model which describe the average daily ground level SO_2 concentrations at Forest Hills, Silver Falls, and Champlain Heights all show highly irregular distributions. The predicted concentrations of SO_2 following the IOL Upgrade ranged from 0.0001 ug/m^3 to almost 9000 ug/m^3 and the distribution was highly skewed. When comparing respective concentrations using these minimum and maximum predicted values, the relative change between existing and future ground level air concentrations ranged from -100% to +2700%. The general consensus is that these wide fluctuations result from the predicted coincidence of SO_2 emissions with highly infrequent meteorological conditions. Therefore, the frequency of occurrence of the maximum predicted values would be rare. Such frequency estimates were not provided in the Stantec (1999a,b) report on air dispersion modelling.

In order to put the modelled air data for ground level SO_2 concentrations into perspective from the point of view of human health, the data were reviewed in terms of the relevance of the predicted values. For Forest Hills, Silver Falls, and Champlain Heights, the model predicted SO_2 concentrations to be below a quantifiable level (0.0001 ug/m^3) for 146, 133, and 126 days out of the year, respectively (Stantec, 1999b). This means that for roughly one third of the year, the emissions from the IOL Refinery, and the other facilities included in the model, contribute little to the SO_2 concentrations in the air at the specified locations.

When there was a measurable air concentration were predicted for both the existing and future scenarios, the mean percent changes between the two scenarios resulting from the decrease in SO_2 emissions were -22.4%, -19.8%, and -19.4% for Forest Hills, Silver Falls, and Champlain Heights, respectively (Table 5-10; Corrected % Change). These values are much more in keeping with the changes in SO_2 emission rates predicted for the IOL facility (at the stack) alone and in combination with the IP and CB facilities (-29% and -17%, respectively).

A portion of the discrepancy between the predicted change for ambient and stack emission values is likely a function of source apportionment. Each source of SO_2 contributes a distinct quantity and has a distinct spatial orientation relative to the site of impact thus for any specific set of meteorological conditions, particularly wind direction, the contribution and thus the significance of that contribution to the total, will change. Thus the final predicted change is the product of a number of competing factors and not a single one as would be the case with a single point source.

Given the relatively high variability associated with the predicted SO_2 concentrations noted at all of the locations, the significance of the decreases indicated above is unclear. Despite the predictions that SO_2 concentrations will decrease, it may not be possible to detect changes of even 22% when natural excursions are in the order of ± 40%. In addition, predicted estimates of SO_2 (Table 5-10; existing study area) were significantly greater than actual measured ambient concentrations at the community monitoring stations (Table 5-9), despite the fact that only a subset of the industrial/urban sources of SO_2 were considered in the air dispersion model. It is likely that a significant portion of the SO_2 experienced at Forest Hills, Silver Falls, and Champlain Heights is from other sources. Given that these sources were not included, but modelled estimates were still high, indicates that the model estimates are very conservative and overestimate air concentrations, especially when short-term average predictions are considered.

The relative impact of the IOL Refinery Upgrade on air quality, based on the air dispersion modelling, can also be examined in terms of the number of predicted exceedances of an air quality benchmark which is reflective of human health concerns. Such exceedances are important in evaluating potential human health concerns. The 24 hour maximum permissible ground level air concentration of 150 ug/m^3 was chosen in order to be directly comparable to the daily averages provided in the Stantec model. For Forest Hills, the model predicted 21 exceedances from the combined sources considered under existing emission rates and 21 exceedances under future emission rates; indicating no predicted change between the two scenarios. For Silver Falls, the model predicted 45 exceedances under existing emission rates and 34 exceedances under future emission rates, giving a relative decrease in exceedances of - 24%. For Champlain Heights, the model predicted 84 exceedances under existing emission rates and 63 exceedances under future emission rates, giving a relative decrease in exceedances of -25%.

A comparison of the predicted exceedances to actual monitoring data (presented in Table 5-9) further supports the conservative nature of the air dispersion modelling and the potential upward bias on the predicted impact of the changes in emission rates resulting from the IOL upgrade. For SO_2, there were no exceedances of the annual average standard (30 ug/m^3) at any of the monitoring sites in 1996, which included Forest Hills, Silver Falls, and Champlain Heights. In 1997 the annual average standard was exceeded at one location (Forest Products), where a value of 36 ug/m^3 was recorded. The use of predicted exceedances associated with 24-hour averages is not directly comparable to actual annual exceedances but it is reasonable to use the predicted changes as a potential maximum thus providing a upper limit on the potential changes in SO_2 concentrations due to the IOL upgrade.

Table 5-10 Predicted[1] SO_2 concentrations for the Existing and Future Study Area Scenarios at a Variety of Receptor Locations in Saint John

Location	Existing Study Area	Future Study Area	% Change[3]	Corrected % Change[4]
1-hr averaging time[2]				
Forest Hills	Max: 20960 $\mu g/m^3$	Max: 20960 $\mu g/m^3$	0%	NA
Champlain Heights	Max: 31440 $\mu g/m^3$	Max: 31440 $\mu g/m^3$	0%	NA
Silver Falls	Max: 20290 $\mu g/m^3$	Max: 20290 $\mu g/m^3$	0%	NA
24-hr averaging time				
Forest Hills	95th percentile: 227 $\mu g/m^3$ mean: 103 $\mu g/m^3$	95th percentile: 166 $\mu g/m^3$ mean: 98 $\mu g/m^3$	-37% -5%	NA
Champlain Heights	95th percentile: 736 $\mu g/m^3$ mean: 254 $\mu g/m^3$	95th percentile: 547 $\mu g/m^3$ mean: 233 $\mu g/m^3$	-35% -9%	NA
Silver Falls	95th percentile: 384$\mu g/m^3$ mean: 164 $\mu g/m^3$	95th percentile: 328 $\mu g/m^3$ mean: 154 $\mu g/m^3$	-17% -6.5%	NA
Annual averaging time				
Forest Hills	mean ± SD: 103 ± 475 $\mu g/m^3$	mean ± SD: 98 ± 472 $\mu g/m^3$	-5 %	-22.4%
Champlain Heights	mean ± SD: 254 ± 932 $\mu g/m^3$	mean ± SD: 233 ± 915 $\mu g/m^3$	-8 %	-19.8%
Silver Falls	mean ± SD: 165 ± 702 $\mu g/m^3$	mean ± SD: 154 ± 695 $\mu g/m^3$	-7 %	-19.4%

[1] Air dispersion models were used to estimate existing and future study area SO_2 concentrations (Stantec, 1999b). These models were considered to be conservative, since the predicted existing study area concentrations are greater than actual measured concentrations in the ambient air monitoring program (see Table 5-9).

[2] Only maximum values were available for the 1-hr averaging time; more realistic values were not available for comparison purposes.

[3] % Changes in predicted SO_2 concentrations from existing to future study area scenarios were determined by subtracting the predicted existing study area concentration from the predicted future study area concentration and converting to a % based on the existing concentration.

[4] Corrected % Change was calculated by comparing each daily existing and future predicted ground level air concentration, and calculating a daily % change. Days wherein the model produced non-quantifiable data were excluded. The daily % changes were then averaged for each location.

NA Not applicable. Corrected % Change could not be calculated using 1 hour or 24 hour average concentrations.

5.3.2 Nitrogen Dioxide

Nitrogen gas is a major component of the earths atmosphere, comprising about 80% of the total mass of gases in ambient air. At high temperatures and under certain conditions, it can combine with oxygen forming several different gaseous compounds collectively referred to as oxides of nitrogen (NOx). Nitric oxide (NO) and nitrogen oxide (NO_2) are the two most important forms from the perspective of human health. Major sources of nitrogen oxides include fuel combustion, particularly from automobiles.

The toxicity of NO_2 is well documented. Exposure to extremely high concentrations may be fatal, while exposures to lesser concentrations can affect lung tissue. In experimental animals, exposures to large enough air concentrations of NO_2 to cause damage to lung tissues can lead to lung disease that resembles emphysema in humans.

Guidelines

The New Brunswick Air Quality standards for NO_2 (*i.e.*, maximum permissible ground level concentrations) are summarized in Table 5-11. These standards are applicable in Saint John and are used as criteria for the assessment of NO_2 emissions from the IOL Refinery. Guidelines for levels of NO_2 in ambient air were also available from the WHO (1999). The WHO (1999) guidelines are more stringent than those of NB DOE (1997) for NO_2. For example, 1-hr averages are 200 versus 400 $\mu g/m^3$ and annual guidelines are 40 versus 100 $\mu g/m^3$ for WHO and NB DOE, respectively.

Background Concentrations

Urban background data (see Table 5-11) for maritime cities, other than Saint John, were obtained from the National Air Pollution Surveillance (NAPS) Network Annual Summary for 1994 and 1997, which was compiled by Environment Canada (1997; 1999). Concentrations of NO_2 were available for a commercial location at 254 Water Street, St. John's; an industrial location at CFB Shearwater, Halifax; and an urban location at 1657 Barrington St., Halifax. These data are summarized in Table 5-11.

When considering the air monitoring data for both 1994 and 1997, the 95th percentile concentration of the 1-hour averaging times ranged from 41 ug/m^3 to 62 ug/m^3. When averaged over 24-hours, the 95th percentile concentrations ranged from 28 ug/m^3 to 51 ug/m^3. Annual averages were only available for Halifax and had a value of 34 ug/m^3 (s.d = 15). Typically, the lowest NO_2 levels were recorded in St. John's, NF, while the highest were in Halifax, NS.

Existing Ambient Concentrations

Data for ambient concentrations in Saint John were available at two locations (Table 5-11). These include residential Forest Hills for 1994-1997, and commercial 189 Prince William for the same time period. Although data are available from previous years, the most recent data were used in order to more accurately represent current trends in air quality.

For all of the Saint John monitoring stations, including the years from 1994 to1997, the 95th % of the 1-hour averaging times ranged from 34 ug/m^3 to 52 ug/m^3. When averaged over 24-hours, the 95th percentile concentrations ranged from 24 ug/m^3 to41 ug/m^3. Annual averages ranged from 11 to 21 ug/m^3.

Comparison of Existing Ambient Concentrations to Background and Guideline Values

Ambient concentrations (95th percentiles) of NO_2 in Saint John are similar if not slightly lower than the background values reported for other maritime cities (Table 5-11). No exceedances of NO_2 were reported by the NB DOE over the 1-hour, 24-hour and/or the annual guidelines at the monitoring stations in Saint John during 1994 and 1997 (NB DOE, 1999b), including Forest Hills, and Prince William. Air concentrations were typically 4 to 5-fold less than their respective air quality objectives. Based on the monitoring data one would not expect residents of Saint John to experience either short-term respiratory responses or chronic health outcomes as a result of exposure to the NO_2 levels present in the city.

Table 5-11 Comparison of NO_x Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
1-hr averaging time			
Forest Hills	1994: 95th percentile: 45 μg/m³ 1997: 95th percentile: 34 μg/m³	1994: commercial: 354 Water Street, St. John's 95th percentile: 62 μg/m³ 1997: commercial: 354 Water Street, St. John's 95th percentile: 41 μg/m³ 1994: industrial: CFB Shearwater, Halifax 95th percentile: 45 μg/m³ 1994: urban: 1657 Barrington, Halifax 95th percentile: 62 μg/m³	200 μg/m³ (WHO, 1999) 400 μg/m³ (NB DOE, 1997)
189 Prince William	1994: 95th percentile: 52 μg/m³ 1997: 95th percentile: 45 μg/m³		
24-hr averaging time			
Forest Hills	1994: 95th percentile: 36 μg/m³ 1997: 95th percentile: 24 μg/m³	1994: commercial: 354 Water Street, St. John's 95th percentile: 47 μg/m³ 1997: commercial: 354 Water Street, St. John's 95th percentile: 28 μg/m³ 1994: industrial: CFB Shearwater, Halifax 95th percentile: 32 μg/m³ 1994: urban: 1657 Barrington, Halifax 95th percentile: 51 μg/m³	200 μg/m³ (NB DOE, 1997)
189 Prince William	1994: 95th percentile: 41 μg/m³ 1997: 95th percentile: 36 μg/m³		
Annual averaging time			
Forest Hills	1994: mean ± SD: 13 ± 17 μg/m³ 1995: mean ± SD: 11 ± 11 μg/m³ 1997: mean ± SD: 11 ± 11 μg/m³	1994: urban: 1657 Barrington, Halifax mean ± SD: 34 ± 15 μg/m³	40 μg/m³ (WHO, 1999) 100 μg/m³ (NB DOE, 1997)

Table 5-11 Comparison of NO_x Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
189 Prince William	1994: mean ± SD: 21 ± 17 $\mu g/m^3$ 1997: mean ± SD: 19 ± 15 $\mu g/m^3$		

Source of ambient air data: NB DOE, 1999f.

Existing and Future Study Area Scenarios

Predicted ground level air concentrations of NO_2 for the study area, under existing and future conditions, were not provided in the Stantec air dispersion modelling report. Therefore, they were estimated using the relationships developed in the air dispersion modelling results for SO_2 (Stantec, 1999b).

The emission sources of NO_2 considered included the combined stack emissions from the IOL Refinery, Courtenay Bay Power Plant (CB), and the Irving Paper Mill (IP). These emissions data were available for both the current and future scenarios. Stack emissions of NO_2 under the current scenario were based on existing stack emissions data available for the facilities of interest. The stack emissions from the IOL facility for the future scenario were obtained by subtracting the contribution from units that were going to be removed as a result of the upgrade and subsequently adding the potential emissions from those units that were being constructed. Estimations of stack emissions for the new units were obtained from the operating specifications supplied by the equipment manufacturer and it is assumed that these represent operating conditions under optimum performance. The contribution of NO_2 from Courtenay Bay Power Plant, and the Irving Paper Mill were assumed to remain constant between the existing and future scenarios.

Calculation of Ground Level NO_x Concentrations

The emission of an ideal gas at a known rate and concentration from a point source will undergo dilution at a predicable rate in known meteorological conditions to reach a point distant from the source at a predictable concentration. All gaseous emissions would behave in the same manner. This is the basis of air dispersion modelling.

The ground level air concentrations of emission gases (X g/m^3) are usually estimated by applying air dispersion modelling algorithms to a "unit emission factor" at the emission source, expressed as 1 gram/second. The result describes the predicted ground level air concentration that would result from a gaseous emission rate of 1 gram per second from the source of emissions. The ground level air concentration value for each chemical of concern at a specific point would be calculated by multiplying the stack emission rate for that chemical times the ground level air concentration at that location as predicted for the unit emission value.

Emissions from multiple process streams or stacks may be treated as a net source for emissions using the algorithms specified in the multiple source air dispersion model used by Stantec (1999a,b).

Dispersion of emissions from the IOL Refinery under existing conditions and under modified circumstances following the upgrade as provided by Stantec (1999a,b) did not include estimates of a unit emission factor for the combined sources of emissions. Only ground level air concentrations of SO_2 for specific stack emission rates of SO_2 were provided.

In the absence of emission factor data, the ground level air concentrations of NO_2 were interpolated from ground level air concentration of SO_2. These calculations estimated local ground level concentrations from the ratio of a specific gaseous emission at "the stack" or unified source and the concentration of SO_2 during the period of interest and the point of interest. Following this procedure, there is a cancellation of the unit emission factors for SO_2 and the specific emission, that would normally be used to calculate ground level air concentrations of the specific emission. For NO_2, the unit emission factors for both SO_2 and NO_2 cancel:

$$NO_2/SO_2 \text{ Stack Ratio: } \quad \frac{\cancel{g}\text{-}SO_2 \ \cancel{\text{per second}}}{\cancel{g}\text{-}NO_2 \ \cancel{\text{per second}}} = \frac{SO_2}{NO_2}$$

$$\text{Ground Level Air Concentration} = [NO_2 / SO_2 \text{ stack ratio}] \text{ X } [\text{Ground Level } SO_2 \ g/m^3]$$

$$= [\text{Ground Level } NO_2 \ g/m^3]$$

The above calculation demonstrates that multiplying the NO_2 / SO_2 stack ratio value times the ground level SO_2 concentration estimated by air dispersion modelling yields the same air concentration estimate for NO_x as would be obtained using the Unit Emission Factor approach.

Results

As discussed, the IOL Refinery Upgrade will involve the decommissioning of specific units as well as the construction of new ones. Modelling of stack emissions, in order to predict future ground level air concentrations, indicated that the facility's contribution to ambient NO_x is expected to increase as a result of the upgrade. The net increase at the stack (as opposed to at ground level) will be roughly 28.5% over existing conditions (IOL, 1999e). When considering the NO_2 contributions from CB and IP, the overall increase in emission rates is 21.1%.

Predicted air quality data were summarized for three locations within the study area: Forest Hills, Silver Falls, and Champlain Heights (See Table 5-12). A comparison of the modelled daily ground level air concentrations of NO_2 at Forest Hills showed an average increase of 13.1 ug/m^3 (95% CI of 7.2) over the 364 days modelled. In relation to the modelled existing mean NO_2 concentrations, at this location (33.0 ug/m^3 with a 95% CI of 15.6), this predicted increase in ground level air concentration amounts to an increase of nearly 40%. The modelled data for Silver Falls and Champlain Heights demonstrated similar trends with increases in ground level NO_2 concentrations of 37% for Silver Falls and 35% for Champlain Heights (Table 5-12).

The potential change in the ground level air concentrations of NO_2 described above as the percent difference between the annual means required careful interpretation because of the highly skewed distributions of the predicted values of average daily ground level NO_2 concentrations at Forest Hills, Silver Falls, and Champlain Heights. Concentrations of NO_2 ranged from 0.00001 ug/m^3 to more than 4000 ug/m^3. When comparing respective concentrations, the relative change between existing and future ranged from -100% to +4000%. In addition, the percent change of the means is greater than the percent increase in stack emissions. This result is very unlikely under real operating conditions. Consequently, the use of mean values as a measure of the central tendency of the air concentrations of NO_2 was not considered reliable.

In order to put the modelled air data for ground level NO_2 concentrations into perspective from the point of view of human health, the data were reviewed in terms of the relevance of the predicted values. For Forest Hills, Silver Falls, and Champlain Heights the model predicted NO_2 concentrations to be below a quantifiable level (0.0001 ug/m^3) for 146, 137, and 126 days out of the year, respectively. Thus for roughly one third of the year, the emissions from the IOL Refinery, and the other facilities included in the model, contribute little or nothing to the NO_2 levels in the air at the specified locations. When there was a quantifiable ground level air concentration predicted from the existing and future scenarios, the mean % change between the two scenarios was +14.0%, +14.7%, and +18.3% for Forest Hills, Silver Falls, and Champlain Heights, respectively (Table 5-12; Corrected % Change). These values are much more in keeping with the changes in NO_2 emission rates predicted for the IOL facility (at the stack) alone and in combination with the IP and CB facilities (+28.5% and +21%, respectively). As with the SO_2 data, a portion of the discrepancy is likely a function of source apportionment between the group of facilities considered in the air dispersion modelling.

Given the relatively high variability associated with the predicted NO_2 concentrations noted at all of the locations, the significance of the increases indicated above is difficult to interpret. Despite the predictions that NO_2 concentrations will increase, it may not be possible to detect changes of even 18% when natural excursions are in the order of ± 100%.

In addition, predicted estimates of NO_2 (Table 5-12) were significantly greater than actual measured ambient concentrations at the community monitoring stations (Table 5-11), despite the fact that only a subset of the industrial/urban sources of NO_2 were considered in the air dispersion model. It is likely that a significant portion of the NO_2 experienced at Forest Hills, Silver Falls, and Champlain Heights is from other sources. Given that these sources were not included, but modelled estimates were still high, indicates that the model estimates are very conservative and the relative change, which is also influenced by other contributing sources, will also be exaggerated.

The relative impact of the IOL Refinery Upgrade on air quality, based on the air dispersion modelling, can also be examined in terms of the number of predicted exceedances of a benchmark value which in turn is reflective of human health concerns. The daily maximum desirable air concentration of NO_2 of 200 ug/m^3 was chosen in order to be directly comparable to the daily averages provided in the Stantec model. For Forest Hills, the model predicted 13 exceedances under existing emission rates and 15 exceedances under future emission rates, giving a relative change of +15%. For Silver Falls, the model predicted 14 exceedances under existing emission rates and 17 exceedances under future emission rates, giving a relative change of +21%. For Champlain Heights, the model predicted 22 exceedances under existing emission rates and 23 exceedances under future emission rates, giving a relative change of +5%. Again, the significance of the relative increase in exceedances predicted by the model is unclear given the current trends in air quality in Saint John, NB.

A comparison of the predicted exceedances to actual monitoring data (Table 5-11) further supports the conservative nature of the air dispersion modelling and the potential upward bias on the predicted impact of the changes in emission rates resulting from the IOL Refinery Upgrade. For NO_2, there were no exceedances of the 1-hour standard (400 ug/m^3) at either the Forest Hills or Customs Building monitoring sites in 1996 or 1997. Neither were the 24-hour standard (200 ug/m^3) or the annual standard (100 ug/m^3) exceeded in either year. It is still reasonable to use the predicted changes as a potential maximum thus providing a upper limit on the potential changes in NO_2 concentrations due to the IOL upgrade. However, the magnitude of the predicted changes at ground level (14 - 18.3% over existing conditions; Table 5-12), are unlikely to have a significant impact on the air quality in Saint John, NB, since the future predicted ground level air concentrations will still be below ambient air quality guidelines.

Table 5-12 Predicted[1] NO_x Concentrations for Existing and Future Study Area Scenarios in Saint John

Location	Existing Study Area	Future Study Area	% Change [2]	Corrected % Change [3]
1-hr averaging time				
Forest Hills	max: 8384 μg/m^3	max: 8384 μg/m^3	0%	NA
Champlain Heights	max: 12576 μg/m^3	max: 12576 μg/m^3	0%	NA
Silver Falls	max: 8116 μg/m^3	max: 8116 μg/m^3	0%	NA
24-hr averaging time				
Forest Hills	95th percentile: 73 μg/m^3	95th percentile: 78 μg/m^3	+ 6.4 %	NA
Champlain Heights	95th percentile: 236 μg/m^3	95th percentile: 257 μg/m^3	+ 8.2%	NA
Silver Falls	95th percentile: 123 μg/m^3	95th percentile: 154 μg/m^3	+ 20%	NA
Annual averaging time				
Forest Hills	mean ± SD: 33 ± 151 μg/m^3	mean ± SD: 46 ± 210 μg/m^3	+ 40 %	+14.0 %
Champlain Heights	mean ± SD: 81 ± 298 μg/m^3	mean ± SD: 110 ± 404 μg/m^3	+ 35 %	+ 14.7%
Silver Falls	mean ± SD: 53 ± 225 μg/m^3	mean ± SD: 72 ± 306 μg/m^3	+ 37 %	+18.3%

[1] Air dispersion models were used to estimate existing and future study area SO_2 concentrations (Stantec, 1999b). NO_2 ground level air concentrations were predicted from these data. These models were considered to be conservative, since the predicted existing study area concentrations are greater than actual measured concentrations in the ambient air monitoring program (see Table 5-11).

[2] % Changes in predicted NO_2 concentrations from existing to future study area scenarios were determined by subtracting the predicted existing study area concentration from the predicted future study area concentration and converting to a % based on the existing concentration.

[3] Corrected % Change was calculated by comparing each daily existing and future predicted ground level air concentration, and calculating a daily % change. Days wherein the model produced non-quantifiable data were excluded. The daily % changes were then averaged for each location.

NA Not applicable. Corrected % Change could not be calculated using 1 hour or 24 hour average concentrations.

Significance of Ground Level NO_2 Concentrations in the Future Study Area Scenario

Modelling of the NO_2 stack emissions, in order to derive future ground level air concentrations, indicated that the upgraded facility's contribution to ambient NO_2 is not expected to increase by more than 28.5%. If other sources of NO_2 are ignored and it is assumed that the modelled stacks account for all of the ambient NO_2 then the maximum increase to the concentrations of NO_2 in the ambient air monitoring stations in the community would also be 28.5%. This worst case approach would result in an increase of the ambient ground level annual average NO_2 concentrations from 21 $\mu g/m^3$ (mean of annual averaging time; Table 5-11) of 28.5% to 27 $\mu g/m^3$. Similarly, 1-hour average NO_2 concentrations would increase from 52 $\mu g/m^3$ (maximum 95th% concentration; Table 5-11) to 67 $\mu g/m^3$. In all cases, these predicted ambient air concentrations of NO_2 are still well below even the most conservative air quality guidelines (annual average guideline: 40 $\mu g/m^3$, WHO, 1999; 1-hour guideline: 200 $\mu g/m^3$, WHO, 1999; see Table 5-11).

5.3.3 Carbon Monoxide

Carbon monoxide (CO), a colourless, odourless, tasteless gas, is a natural constituent of the earths atmosphere. However, under certain conditions, especially in calm weather during winter and spring when fuel combustion reaches a peak and cooler temperatures restrict its further reaction, it may temporarily reach potentially harmful levels. Important sources of CO include:

- automobile emissions;
- home/building heating;
- volcanoes, thunderstorms, and forest fires;
- vegetation, and
- chemical oxidation of methane gas.

Guidelines

The New Brunswick Air Quality standards for CO (*i.e.*, maximum permissible ground level concentrations) are summarized in Table 5-13. These standards are applicable in Saint John and will serve as benchmarks for the assessment of CO emissions from the IOL Refinery. Guidelines for levels of CO in ambient air were also available from the WHO (1999). Generally, WHO (1999) guidelines are more stringent than those of NB DOE (1997) for carbon monoxide. For example, 1-hr averages are 30 versus 35 mg/m^3 for WHO and NB DOE, respectively. Additionally, WHO has 15-min, 30-min, and 8-hr guidelines of 100, 60, and 10 mg/m^3, respectively.

Background Concentrations

Urban background data for maritime cities, other than Saint John, were obtained from the National Air Pollution Surveillance (NAPS) Network Annual Summary for 1994 and 1997, which was compiled by Environment Canada (1997, 1999). Concentrations of CO were available for a commercial location at 254 Water Street, St. and an urban location at 1657 Barrington St., Halifax. These data are summarized in Table 5-13.

When considering the air monitoring data for both 1994 and 1997, the 95th % concentrations of the 1-hour averaging times ranged from 0.9 mg/m^3 to 1.6 mg/m^3. When averaged over 8-hours, the 95th % concentration ranged from 0.8 mg/m^3 to 1.4 mg/m^3. Values for 24-hour time frames and annual averages were only available for St. John's, NF, and had values of 0.7 mg/m^3 and 0.3 mg/m^3 (s.d = 0.3). Typically, the lowest CO levels were recorded in St. John's, NF, while the highest were in Halifax, Nova Scotia.

Existing Ambient Concentrations in Saint John

Ambient levels of carbon monoxide in Saint John were available from a monitoring station located at 189 Prince William (commercial location) for 1994-1997 and are presented in Table 5-13. Although data are available from previous years, the most recent data were used in order to more accurately represent current trends in air quality.

When considering the years from 1994 to1997, the 95th % concentration of the 1-hour averaging times ranged from 1.7 mg/m^3 to 2.6 mg/m^3. When averaged over 8-hours, the 95th % concentration ranged from 1.6 mg/m^3 to 2.5 mg/m^3. The annual average was 1.5 mg/m^3.

Comparison of Existing Ambient Concentrations to Background Levels and Guideline Values

Ambient concentrations (95th percentiles) of CO in Saint John are similar or slightly higher than the background values reported for other maritime cities (Table 5-13). No exceedances of CO were reported by the NB DOE over the 1-hour, and 8-hour guidelines at the Prince William monitoring station in Saint John (NB DOE, 1999b). Air concentrations were significantly less than their respective air quality objectives. Based on the monitoring data one would not expect residents of Saint John to experience either short-term responses or chronic health outcomes as a result of exposure to the CO levels present in the city.

Table 5-13 Comparison of Carbon Monoxide Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
1-hr averaging time			
189 Prince William	1994: 95th percentile:1719 μg/m^3 1997: 95th percentile: 2600 μg/m^3	commercial: 254 Water Street, St. John's 1994: 95th percentile:1490 μg/m^3 1997: 95th percentile: 900 μg/m^3 urban: 1657 Barrington St., Halifax 1994: 95th percentile:1604 μg/m^3	30,000 μg/m^3 (WHO, 1999) 35,000 μg/m^3 (NB DOE, 1997)

Table 5-13 Comparison of Carbon Monoxide Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
8-hr averaging time			
189 Prince William	1994: 95th percentile: 1604 $\mu g/m^3$ 1997: 95th percentile: 2500 $\mu g/m^3$	commercial: 254 Water Street, St. John's 1994: 95th percentile: 1261 $\mu g/m^3$ 1997: 95th percentile: 800 $\mu g/m^3$ urban: 1657 Barrington St., Halifax 1994: 95th percentile: 1375 $\mu g/m^3$	10,000 $\mu g/m^3$ (WHO, 1999) 15,000 $\mu g/m^3$ (NB DOE, 1997)
24-hr averaging time			
189 Prince William	1997: 95th percentile: 2400 $\mu g/m^3$	commercial: 254 Water Street, St. John's 1997: 95th percentile: 700 $\mu g/m^3$	no guideline available
Annual averaging time			
189 Prince William	1997: mean ± s.d.: 1300 $\mu g/m^3$ ± 600	commercial: 254 Water Street, St. John's 1997: mean ± s.d.: 300 $\mu g/m^3$ ± 300	no guideline available

Source of ambient air data: NB DOE, 1999f.

Existing and Future Study Area Scenario Assessment

Predicted ground level air concentrations of CO for the study area, under existing and future conditions, were estimated using the relationships developed in the air dispersion modelling conducted for SO_2 (Stantec, 1999b). The emission sources of CO considered included the combined stack emissions from the IOL Refinery, Courtenay Bay Power Plant (CB), and the Irving Paper Mill (IP). These emissions data were available for both the current and future scenarios. Stack emissions of CO under the current scenario were based on existing stack emissions data available for the facilities of interest.

The stack emissions from the IOL Refinery for the future scenario were obtained by subtracting the contribution from units that were going to be removed as a result of the upgrade and subsequently adding the potential emissions from those units that were being constructed. Estimations of stack emissions for the new units were obtained from the operating specifications supplied by the equipment manufacturer and thus represent operating conditions under optimum performance. The contribution of CO from Courtenay Bay Power Plant, and the Irving Paper Mill were assumed to remain constant between the existing and future scenarios.

Dispersion of CO emissions from the IOL Refinery under existing conditions and under modified circumstances following the upgrade did not include estimates for unit emission factors (see discussion of this issue in Section 5.3.2 on NO_x). As an alternative, ground level air concentrations of SO_2 predicted at specific sites within the study area, and the ratios of stack emission rates for SO_2 and CO were supplied. In the absence of unit emission factor data, the ground level air concentrations of CO were interpolated by multiplying the ground level air concentration of SO_2 times the SO_2 /CO stack emission ratio. As in Section 5.3.2 for NO_x , the unit emission factors for

SO_2 and CO cancel, yielding the ground level air concentration estimate for CO (see example):

$$\text{CO/SO}_2 \text{ Stack Ratio: } \frac{\text{g-SO}_2\ \cancel{\text{per second}}}{\text{g-CO}\ \cancel{\text{per second}}} = \frac{\text{SO}_2}{\text{CO}}$$

Ground Level Air Concentration = [CO / SO_2 stack ratio] X [Ground Level SO_2 g/m^3]

= [Ground Level CO g/m^3]

As discussed, the IOL Refinery Upgrade will involve the decommissioning of specific units as well as the construction of new ones. Modelling of stack emissions, in order to predict future ground level air concentrations, indicated that the facility's contribution to ambient CO is expected to increase as a result of the upgrade (Table 5-14). The net increase (based on stack emissions) will be roughly 37.1% over existing conditions. When considering the CO contributions from CB and IP, the overall increase in emission rates is less at 33.5%.

Predicted air quality data was summarized for three locations within the study area: Forest Hills, Silver Falls, and Champlain Heights (See Table 5-14). A comparison of the modelled daily ground level air concentrations of CO at Forest Hills showed an average increase of 3.6 ug/m^3 (95% CI of 1.9) over the 364 days modelled. In relation to the modelled existing mean CO concentrations, at this location (7.2 ug/m^3 with a 95% CI of 3.4), there was an increase of nearly 50%. The modelled data for Silver Falls and Champlain Heights demonstrated similar trends with increases in ground level CO concentrations of 47% for Silver Falls and 44% for Champlain Heights.

The potential change in the ground level air concentrations of CO described above as the percent difference between the annual means is not necessarily relevant to the evaluation of potential human health effects from CO. The data sets produced by the model which describe the average daily ground level CO concentrations at Forest Hills, Silver Falls, and Champlain Heights all possess highly irregular distributions. Concentrations of CO ranged from 0.00001 ug/m^3 to almost a 1000 ug/m^3 and the distribution was highly skewed. When comparing respective concentrations, the relative change between existing and future ranged from -100% to +4300%. In addition, the percent change of the means is greater than the percent increase in stack emissions, which is very unlikely. Consequently, the use of a mean as a measure of the central tendency is expected to be unreliable and not meaningful from a human health point of view.

In order to put the modelled air data for ground level CO concentrations into perspective from the point of view of human health, the data was reviewed in terms of the relevance of the predicted values. For Forest Hills, Silver Falls, and Champlain Heights the model predicted CO concentrations to be below a quantifiable level (0.0001 ug/m^3) for 146, 137, and 126 days out of the year, respectively. Thus for roughly one third of the year, the emissions from the IOL Refinery, and the other facilities included in the model, contribute little or nothing to the CO levels in the air at the specified locations. When there was a quantifiable air concentration associated with both the existing and future scenarios, the mean percent change at ground level between the two scenarios, that resulted from the increase in CO emissions, was +22.0%, +22.0%, and +24.3% for Forest Hills, Silver Falls, and Champlain Heights, respectively (Table 5-14; Corrected % Change).

These values are much more in keeping with the changes in CO emission rates predicted for the IOL facility alone and in combination with the IP and CB facilities (+37% and +33%, respectively). As with the SO_2 and the NO_2 data, a portion of the discrepancy is likely a function of source apportionment. Each source of CO contributes a distinct quantity and has a distinct spatial orientation relative to the site of impact thus for any specific set of meteorological conditions, particularly wind direction, the contribution and thus the significance of that contribution to the total, will change. Thus the final predicted change is the product of a number of competing factors and not a single one as would be the case with a single point source.

Given the relatively high variability associated with the predicted CO concentrations noted at all of the locations, the significance to human health of the increases indicated above is difficult to interpret. Despite the predictions that CO concentrations will increase, it may not be possible to detect changes of even 24% when natural excursions are in the order of ± 46%. Contrary to what was observed with both SO_2 and NO_2, predicted estimates of CO were significantly lower than actual measured ambient concentrations at the community monitoring stations. Although no ambient monitoring data were available for Forest Hills, Silver Falls, and Champlain Heights, annual average concentration at 189 Prince William, in Saint John, was 1300 ug/m^3 (± 0.7)(Table 5-13) while predicted averages ranged from 7.2 to only 17.8 ug/m^3 (Table 5-14). Only a subset of the industrial/urban sources of CO were considered in the air dispersion model and it is likely that a significant portion of the CO experienced in Saint John is from other sources.

The relative impact of the IOL facility upgrade on air quality, based on the air dispersion modelling, can also be examined in terms of the number of predicted exceedances of a benchmark value which in turn is reflective of human health concerns. The 8-hour maximum desirable level of 6000 ug/m^3 was chosen in order to be comparable to the daily averages provided in the Stantec model. For Forest Hills, Silver Falls, and Champlain Heights the model predicted zero exceedances under existing emission rates and zero exceedances under future emission rates, giving a relative change of 0%. A comparison of the predicted exceedances to actual monitoring data further shows agreement. For CO, peak hourly values in every month were well below the applicable standard of 35 mg/m^3 in both 1996 and 1997. There were also no exceedances of the 8-hour standard of 15 mg/m^3 in either year. It is still reasonable to use the predicted changes as a potential maximum thus providing a upper limit on the potential changes in CO concentrations due to the IOL Refinery Upgrade. However, the magnitude of the predicted changes, are unlikely to have a significant impact on the air quality in Saint John, N.B.

Table 5-14 Predicted[1] Carbon Monoxide Concentrations for Existing and Future Study Area Scenarios in Saint John

Location	Existing Study Area	Future Study Area	% Change [2] Based on Means	Corrected % Change [3]
1-hr averaging time				
Forest Hills	max: 1886 $\mu g/m^3$	max: 1886 $\mu g/m^3$	0%	NA
Champlain Heights	max: 2830 $\mu g/m^3$	max: 2830 $\mu g/m^3$	0%	NA
Silver Falls	max: 1826 $\mu g/m^3$	max: 1826 $\mu g/m^3$	0%	NA
24-hr averaging time				
Forest Hills	95th percentile: 16 $\mu g/m^3$	95th percentile: 18 $\mu g/m^3$	+ 11%	NA
Champlain Heights	95th percentile: 52 $\mu g/m^3$	95th percentile: 60 $\mu g/m^3$	+ 13%	NA
Silver Falls	95th percentile: 27 $\mu g/m^3$	95th percentile: 36 $\mu g/m^3$	+ 25%	NA
Annual averaging time				
Forest Hills	7.2 $\mu g/m^3 \pm 33$	10.8 $\mu g/m^3 \pm 50$	+ 50%	+ 22%
Champlain Heights	17.8 $\mu g/m^3 \pm 49$	25.7 $\mu g/m^3 \pm 71$	+ 44%	+ 22%
Silver Falls	11.5 $\mu g/m^3 \pm 65$	16.9 $\mu g/m^3 \pm 95$	+ 47%	+ 24.3%

[1] Air dispersion models were used to estimate existing and future study area SO_2 concentrations (Stantec, 1999b). CO ground level air concentrations were predicted from these data. These models predicted existing study area concentrations which are less than actual measured concentrations in the ambient air monitoring program (see Table 5-13).

[2] % Changes in predicted CO concentrations from existing to future study area scenarios were determined by subtracting the predicted existing study area concentration from the predicted future study area concentration and converting to a % based on the existing concentration.

[3] Corrected % Change was calculated by comparing each daily existing and future predicted ground level air concentration, and calculating a daily % change. Days wherein the model produced non-quantifiable data were excluded. The daily % changes were then averaged for each location.

NA Not applicable. Corrected % Change could not be calculated using 1 hour or 24 hour average concentrations.

Significance of Ground Level CO Concentrations in the Future Study Area Scenario

Modelling of the CO stack emissions, in order to derive future ground level air concentrations, indicated that the upgraded facility's contribution to ambient CO is not expected to increase by more than 37.1%. If other sources of CO are ignored and it is assumed that the modelled stacks account for all of the ambient CO, then the maximum increase to the concentrations of CO at the ambient air monitoring stations in the community would also be 37.1%. This worst case approach would result in an increase of the ambient ground level CO concentrations from 2600 $\mu g/m^3$ (95th% of 1-hr averaging time; Table 5-13) by 37.1% to 3565 $\mu g/m^3$. This predicted ambient air concentration of CO is still well below air quality guidelines (see Table 5-13).

Based on this evaluation, no measurable adverse health effects would be expected in the community from the changes in ground level CO related to the IOL Refinery Upgrade.

5.4 Particulate Matter

Tiny airborne particles or aerosols that are less than 100 microns in diameter, are collectively referred to as the total suspended particulate matter (TSP). These particles are constantly entering the atmosphere from a variety of sources. Natural sources include soil, pollen, moulds, fungi, and other organic material. Human sources include combustion products, industrial processes, power generation, building heating systems and motor vehicles.

Over 99% of the particulate matter that is inhaled is either subsequently exhaled or trapped in the upper areas of the respiratory system and expelled or swallowed in mucous. The balance enters the windpipe and lungs, where some particulates, known as inhalable particulates, cling to protective mucous lining of the respiratory tract. These trapped particles are slowly removed via a number of clearing mechanism such as coughing. Some of the smallest particles, referred to as respirable particulates (PM_{10} or $PM_{2.5}$) reach the bronchioles and alveoli of the lung where they have the potential of causing adverse effects.

The people most sensitive to the effects of respirable particulate matter include those with heart problems, or respiratory diseases such as emphysema, bronchitis, and asthma. The adverse health effects from particulate matter are often not immediately diagnosed. Repeated, long term exposures to extreme air concentrations of respirable particulate matter can lead to accumulation of retained particles in the lungs. If this accumulation overloads the ability of the lung to absorb and degrade these particles, they can contribute to respiratory diseases later in life. In addition to the physical irritation and obstruction, the chemical composition of some particulate matter may cause various toxic effects if inhaled and absorbed in sufficient quantity. In this case, the natural clearing mechanisms are not as effective since the ingestion of mucous laden with toxic particulate matter represents a route of exposure. In addition, some of the chemicals on the particulate matter, for example, various metals, may detach from the particles and be absorbed into the blood through the alveoli of the lung.

The potential impacts of particulate matter on public health within the community of Saint John, NB, was evaluated from the perspective of the IOL Refinery Upgrade. The results for PM_{10}, $PM_{2.5}$ and TSP (total suspended particulates) are presented in Sections 5.4.1, 5.4.2 and 5.4.3, respectively. For each case, the particulate matter related to the IOL Refinery Upgrade was assessed by comparing existing ambient and predicted future concentrations to background values from monitoring locations other than Saint John, and ambient air quality guidelines.

5.4.1 Particulate Matter - PM_{10}

Guidelines

The guidelines for PM_{10} are summarized in Table 5-15. Health Canada / Environment Canada (HC/EC, 1999) recently recommended a 24-hour Reference Level of 25 $\mu g/m^3$ below which adverse health outcomes have not been observed. A Canada Wide Standard (CWS) of 50 $\mu g/m^3$ has also recently been proposed (CWSDCPMO, 1999) as a working level standard that would not be expected to result in substantial risks of adverse health outcomes. The HC/EC (1999) Reference Level of 25 $\mu g/m^3$ is an estimate of the lowest ambient PM_{10} air concentration at which statistically significant increases in health responses can be detected, based on available data and current technology. However, HC/EC (1999) indicated that the Reference Level should not be interpreted as an effects threshold. CRESTec/NERAM (1999) concluded that the reason for this conclusion is that the methodologies used to establish the HC/EC (1999) value of 25 µg/m^3 are not sufficiently precise or sensitive to delineate the existence of a threshold.

Background Concentrations of PM_{10} Particulate Matter

Background concentrations of PM_{10} were not available from monitoring data and were estimated using the TSP background data and by applying the following relationship:

$$PM_{10} = 10^{(0.826 \times \log TSP)} \text{ (HC/EC, 1999)}$$

Measured PM_{10} background data for 1984-1995 (combined) were available for four urban locations in Atlantic Canada (Duckworth/Ordinance, St. John's; Nova Scotia Technical University, Halifax; 1657 Barrington Street, Halifax; and Harbour View School, Dartmouth); and one rural location in Kejimkujik National Park (HC/EC, 1999). The upper 90th percentile concentration of these particulates in the air ranged from 19 to 40 ug/m^3. Both the estimated and measured PM_{10} data are presented in Table 5-15.

Existing Ambient Ground Level Air Concentrations of PM_{10} in Saint John

Data for ambient ground level air concentrations of particulate matter in Saint John were available at two locations. These included 110 Charlotte Street for 1994 (PM_{10} was measured in 1997; concentrations calculated from 1994 data on TSP concentrations); and Forest Hills for 1984-1995 (measured PM_{10}) and for 1994-1998 (PM_{10} concentrations calculated from TSP data).

Calculated and measured ground level ambient concentrations of PM_{10} in Saint John are similar to values calculated or measured for the other maritime locations considered in the background evaluation. The only exceedances over the HC/EC (1999) recommended 24 hour Reference Level of 25 µg/m^3 were the 90th percentile measured 24 hour data (*i.e.*, 28 µg/m^3), and the 95th percentile measured 24 hour data (30 µg/m^3), both in Forest Hills. Other measured or estimated data in Saint John are below the recommended and proposed air quality guidelines presented in Table 5-15. Both the 90th and 95th percentile values for Forest Hills were less than the CWSDCPMO (1999) standard of 50 µg/m^3.

Table 5-15 Comparison of PM_{10} Ambient Levels in Saint John to Background and Guidelines [1]

Location	24-hr Ambient	24-hr Background (90th percentile for 1984-1995)	24-hr Guideline(s)
110 Charlotte St.	1994 50th percentile: 15 $\mu g/m^3$ (estimated) 1994 90th percentile: 24 $\mu g/m^3$ (estimated)	rural: Kejimkujik National Park 21 $\mu g/m^3$ urban: Duckworth/Ordinance, St. John's 29 $\mu g/m^3$ urban: NS Technical University, Halifax 40 $\mu g/m^3$ urban: 1657 Barrington St., Halifax 22 $\mu g/m^3$ urban: Harbor View School, Dartmouth 19 $\mu g/m^3$	[2]25 $\mu g/m^3$ (HC/EC, 1999) (recommended 24 hour average) [3]50 $\mu g/m^3$ (CWSDCPMO 1999) (proposed)
Forest Hills	1994 50th percentile: 12 $\mu g/m^3$ (estimated) 1984-1995 90th percentile: 28 $\mu g/m^3$ (measured) 1997: 95th percentile: 30 $\mu g/m^3$ (measured) 1997: Annual average 15 ± 12 ug/m^3		

[1] 50th and 90th percentile values are presented as provided by original data sources (95th percentile values were not available from these sources).

[2] The HC/EC (1999) recommended Reference Level of 25 µg/m^3 is an estimate of the lowest ambient PM_{10} air concentration at which statistically significant increases in health responses can be detected, based on available data and current technology. However, HC/EC (1999) indicated that the Reference Level should not be interpreted as an effects threshold.

[3] The proposed CWS is based on both health protection considerations and technical and economic feasibility. Achievement of the proposed 24 hour CWS of 50 µg/m^3 will be determined based on 98% of measurements, each of which is an average of measurements taken over a 24 hour period, falling below this target value, when averaged over three consecutive years (CWSDCPMO, 1999).

Existing and Future Study Area Evaluation of PM_{10} Concentrations

Concentrations of PM_{10} were predicted using the relationship given below, from the predicted ground level concentrations of TSP for the existing and future study areas as modelled by Stantec (1999a):

$$PM_{10} = 10^{(0.826 \times \log TSP)} \text{ (HC/EC, 1999)}$$

Predicted concentrations of particulate matter from Stantec (1999a) were based on current (IOL present, CB, IP, Lantic Sugar (LS) and Irving Pulp and Paper (IPP)) or predicted future emission rates (IOL upgraded, CB, IP, LS, IPP) and on meteorological data from the Saint John area for 1997-1998. All particulate sources modelled were assumed to be combustion-related. Based on an analysis of the Stantec (1999a) data, the IOL Refinery contribution to ground level ambient air concentrations of PM_{10} is predicted to increase marginally following the Upgrade (Table 5-16).

Table 5-16 Predicted 24-hr Ground Level PM_{10} Concentrations for Existing and Future Study Area in Saint John

Location	Existing Study Area Scenario 24-hr 95th Percentile	Future Study Area Scenario 24-hr 95th Percentile	% Change
Forest Hills	2.0 μg/m^3	2.2 μg/m^3	+ 10%
Champlain Heights	6.6 μg/m^3	7.1 μg/m^3	+ 7.5%
Silver Falls	3.7 μg/m^3	4.1 μg/m^3	+ 11%

Potential Impact of the Ground Level PM_{10} Concentrations for the Future Study Area

The evaluation summarized in Table 5-16 indicates that the ambient ground level air concentrations of PM_{10} related to the future study area would not be expected to increase by more than 11%. If it is assumed that other sources of PM_{10} entering the community air shed are insignificant (*i.e.*, the modelled stacks account for all of the ambient PM_{10}), then the maximum increase to the ground level ambient air concentrations at the community monitoring stations would also be 11%. These predictions indicate that the maximum increase of ground level ambient air concentrations of PM_{10} following the IOL Refinery Upgrade would be from between 15 μg/m^3 - 24 μg/m^3 (Table 5-15) to between 17 μg/m^3 - 27 μg/m^3 at the Charlotte Street monitoring station. At the Forest Hills monitoring station the PM_{10} would increase from values between 12 μg/m^3 - 30 μg/m^3 (Table 5-15) to values between 13 μg/m^3 - 33 μg/m^3 at the Forest Hills monitoring station.

However, the actual contribution of the IOL Refinery to the current level of particulate matter in the air is expected to be less than those predicted above, given the numerous other potential sources. Even without considering this reduction in contribution due to the existence of other sources of PM_{10}, the predicted air concentrations are either within recommended or proposed air CWSDCPMO (1999) quality guideline of 50 μg/m^3 (see Table 5-15), or slightly exceed the HC/EC (1999) no-measurable effect, 24 hour Reference Level of 25 μg/m^3. Therefore, no measurable adverse public health outcomes would be expected in the community from the IOL Refinery Upgrade based on the future study area scenario. An important reason for this conclusion is that the estimated increase in particulate will likely result in concentrations which are already occurring within the Saint John area (in the absence of the upgrade), and thus it will not be possible to denote a measurable change in health outcomes related to exposure to this parameter.

It must be recognized that the PM_{10} values used in the above assessment were based on values calculated from total suspended particulate matter, and were not actually measured values. Therefore, the above conclusions are contingent on validation of the PM_{10} concentrations in the community.

5.4.2 Particulate Matter - $PM_{2.5}$

Guidelines

The guidelines for $PM_{2.5}$ are summarized in Table 5-17. Health Canada / Environment Canada (HC/EC, 1999) recently recommended 24-hour Reference Level of 15 $\mu g/m^3$ below which no adverse health outcomes were measurable. A Canada Wide Standard (CWS) of 25 $\mu g/m^3$ has recently been proposed (CWSDCPMO, 1999). The Reference Level of 15 $\mu g/m^3$ is an estimate of the lowest ambient $PM_{2.5}$ air concentration at which statistically significant increases in health responses can be detected, based on available data and current technology. However, the Reference Level should not be interpreted as an effects threshold (HC/EC, 1999). As with the PM_{10} parameter, CRESTec /NERAM (1999) concluded that the reason for this conclusion is that the methodologies used to establish the HC/EC (1999) value of 25 $\mu g/m^3$ are not sufficiently precise or sensitive to delineate the existence of a threshold.

Background Concentrations of $PM_{2.5}$

As with PM_{10}, background concentrations of $PM_{2.5}$ were estimated by applying the following relationship to the background TSP data:

$$PM_{2.5} = 10^{(0.636 \times \log TSP)} \text{ (HC/EC, 1999)}$$

In addition, measured $PM_{2.5}$ background data for 1984-1995 (combined) were available for four urban locations (Duckworth/Ordinance, St. John's; Nova Scotia Technical University, Halifax; 1657 Barrington Street, Halifax; and Harbour View School, Dartmouth); and one rural location in Kejimkujik National Park (HC/EC, 1999). The upper 90th percentile concentration of these particulates in the air ranged from 11 to 25 ug/m^3 Both the estimated and measured $PM_{2.5}$ data are presented in Table 5-17.

Existing Ambient Ground Level Air Concentrations of $PM_{2.5}$ in Saint John

Estimates of ambient ground level air concentrations of $PM_{2.5}$ in Saint John were available at two locations: 110 Charlotte Street for 1994 (estimated from TSP data); and Forest Hills for 1984-1995 (measured), for 1994-1998 (estimated from TSP data), and for 1997 (measured). These data are summarized in Table 5-17.

Estimated ambient ground level air concentrations of $PM_{2.5}$ in Saint John exceed the most stringent Canadian guideline (1984-95 90th percentile; 1997 95th percentile values), but not in all cases (Table 5-17). All values are less than the proposed Canada Wide Standard (Table 5-15). The values in Saint John are comparable to those reported for urban background locations in other maritime communities, and are lower than values reported for downtown Halifax, NS.

Table 5-17 Comparison of $PM_{2.5}$ Ambient Levels in Saint John to Background and Guidelines[1]

Location	24-hr Ambient	24-hr Background (90^{th} percentile for 1984-1995)	24-hr Guideline(s)
110 Charlotte St.	1994 50^{th} percentile: 8 $\mu g/m^3$ (estimated)	rural: Kejimkujik National Park 13.6 $\mu g/m^3$	[2] 15 $\mu g/m^3$ (HC/EC, 1999) (recommended 24 hour average) [3] 25 $\mu g/m^3$ (CWSDCPMO 1999) (proposed)
	1994 90^{th} percentile: 11.6 $\mu g/m^3$ (estimated)	urban: Duckworth/Ordinance, St. John's 18 $\mu g/m^3$	
	1994 maximum: 12.2 $\mu g/m^3$ (estimated)	urban: NS Technical University, Halifax 25 $\mu g/m^3$	
Forest Hills	1994 50^{th} percentile: 7 $\mu g/m^3$ (estimated)	urban: 1657 Barrington St., Halifax 15.1 $\mu g/m^3$	
	1984-1995 90^{th} percentile: 16.2 $\mu g/m^3$ (measured)	urban: Harbor View School, Dartmouth 10.9 $\mu g/m^3$	
	1997: 95^{th} percentile 19 ug/m^3		
	1997: annual average 9 ± 7 ug/m^3		

[1] 50^{th} and 90^{th} percentile values are presented as provided by original data sources (95^{th} percentile values were not available from these sources).

[2] The HC/EC (1999) recommended Reference Level of 15 $\mu g/m^3$ is an estimate of the lowest ambient $PM_{2.5}$ air concentration at which statistically significant increases in health responses can be detected, based on available data and current technology. However, HC/EC (1999) indicated that the Reference Level should not be interpreted as an effects threshold.

[3] The proposed CWS is based on both health protection considerations and technical and economic feasibility. Achievement of the proposed 24 hour CWS of 25 $\mu g/m^3$ will be determined based on 98% of measurements, each of which is an average of measurements taken over a 24 hour period, falling below this target value, when averaged over three consecutive years (CWSDCPMO, 1999).

Existing and Future Study Area Predicted Concentrations of $PM_{2.5}$

Predicted ground level concentrations of $PM_{2.5}$ were estimated using the TSP data modelled by Stantec (1999a) based on the following relationship:

$$PM_{2.5} = 10^{(0.636 \times \log TSP)} \text{ (HC/EC, 1999)}$$

Although the air dispersion models tend to over predict ground level air concentrations of particulate matter (See discussion on SO_2, Section 5.3.1), the $PM_{2.5}$ concentrations estimated from background and ambient TSP data are less than those actually measured at the same sites. This suggests that the IOL Refinery is not a significant contributor to fine particulate matter in the area.

As previously indicated, predicted concentrations of particulate by Stantec (1999a) were based on current (IOL present, CB, IP, Lantic Sugar (LS) and Irving Pulp and Paper (IPP)) or predicted future emission rates (IOL upgraded, CB, IP, LS, IPP) and on meteorological data for 1997-1998. Based on an analysis of the Stantec (1999a) data the IOL Refinery contribution to ambient $PM_{2.5}$ levels is expected to increase only marginally following the upgrade (Table 5-18).

Table 5-18 Predicted 24-hr $PM_{2.5}$ concentrations for the Existing and Future Study Area Scenarios in Saint John

Location	Existing Study Area 24-hr 95th Percentile	Future Study Area 24-hr 95th Percentile	% Change
Forest Hills	1.7 $\mu g/m^3$	1.8 $\mu g/m^3$	+ 6%
Champlain Heights	4.3 $\mu g/m^3$	4.5 $\mu g/m^3$	+ 5%
Silver Falls	2.8 $\mu g/m^3$	3.0 $\mu g/m^3$	+ 7%

Potential Impact of the Ground Level $PM_{2.5}$ Concentrations for the Future Study Area

The evaluation summarized in Table 5-18 indicates that the increase in ambient ground level air concentrations of $PM_{2.5}$ following the IOL Refinery Upgrade future study area would be expected to increase by 7% or less. If all other potential sources of $PM_{2.5}$ are ignored and it is assumed that the modelled stacks account for all of the ambient $PM_{2.5}$, then the maximum increase to the ambient ground level concentrations at the community monitoring stations would also be 7%. This would result in an increase in the highest ambient $PM_{2.5}$ level of 19 $\mu g/m^3$ (95th percentile observed at Forest Hills) to a value of 20.3 $\mu g/m^3$. This predicted 95th percentile air concentration of $PM_{2.5}$ at the Forest Hills monitoring station marginally (1.4-fold) exceeds the minimum air concentration of 15 $\mu g/m^3$ below which adverse health outcomes could not be measured (HC/EC, 1999). The predicted 95th percentile air concentration of $PM_{2.5}$ at the Forest Hills monitoring station is less than the proposed Canada-Wide Standard of 25 $\mu g/m^3$.

The actual contribution of the IOL Refinery to the current level of particulate matter in the air is expected to be less than those summarized above, given the numerous other potential sources of $PM_{2.5}$ in the region.

The ambient air quality criteria summarized in Table 5-17 represent a highly conservative interpretation of the available scientific information. Therefore, we are confident that no measurable adverse public health outcomes would be expected beyond those that currently exist in the community from the predicted $PM_{2.5}$ concentrations. Since the IOL Refinery Upgrade is the single difference in the industrial emissions between the existing study area and the future study area scenarios, the contribution from the IOL Refinery Upgrade would not result in measurable adverse public health outcomes in the community.

As indicated previously, it must be recognized that the $PM_{2.5}$ values used in the above assessment were based on values calculated from total suspended particulate matter, and were not actually measured values. Therefore, the above conclusions are contingent on validation of the $PM_{2.5}$ concentrations in the community.

5.4.3 Total Suspended Particulate (TSP)

Guidelines

The guidelines for total suspended particulates (TSP) are summarized in Table 5-19. NB DOE (1997) provided a 24-hr guideline of 120 μg/m³ and an annual guideline of 70 μg/m³ for TSP.

Background Concentrations

Background data for six maritime cities, other than Saint John, were obtained from the National Air Pollution Surveillance (NAPS) Network Annual Summary for 1994 and 1997, which was compiled by Environment Canada (1997, 1999, respectively). These data are summarized in Table 5-19. Locations with available data for TSP included five commercial locations (354 Water Street, St. John's; 56 Fitzroy Street, Charlottetown; Technical University of Nova Scotia, Halifax; County Jail, Sydney; and York Street, Fredericton); three residential locations (Dalhousie University, Halifax; Whitney Pier Fire Station, Sydney; and South Street, Glace Bay); and one industrial location in CFB Shearwater, Halifax. NB DOE provided additional background data from York Street, Fredericton for 1995 and 1996. In summary, the upper 90th percentile concentration of these particulates in the air ranged from 18 to 65 ug/m³, when averaged over 24-hours, and from 13 to 26 for the annual averaging time.

Existing Ambient Ground Level Air Concentrations of TSP in Saint John

Data for ambient concentrations of TSP in Saint John were available for two locations in 1994 and 1996-1998: 110 Charlotte Street and Forest Hills. These data are summarized in Table 5-19.

Ambient ground level air concentrations of TSP in Saint John are similar to values measured in other maritime cities (designated as urban background). In addition, these ambient concentrations are well below current NB DOE air quality guidelines for TSP (Table 5-19).

Table 5-19 Comparison of TSP Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
24-hr averaging time			
Forest Hills	1994: 50th percentile: 21 µg/m^3 1994: 90th percentile: 35 µg/m^3 1997: 90th percentile: 77 µg/m^3	commercial: 254 Water Street, St. John's 1994: 90th percentile: 30 µg/m^3 1997: 90th percentile: 33 µg/m^3 commercial: 56 Fitzroy St., Charlottetown 1994: 90th percentile: 27 µg/m^3 1997: 90th percentile: 33 µg/m^3 commercial: Technical University of NS 1994: 90th percentile: 40 µg/m^3 1997: 90th percentile: 42 µg/m^3 residential: Dalhousie University, Halifax 1994: 90th percentile: 24 µg/m^3 1997: 90th percentile: 25 µg/m^3 industrial: CFB Shearwater, Halifax 1994: 90th percentile: 18 µg/m^3 1997: 90th percentile: 21 µg/m^3 commercial: County Jail, Sydney 1994: 90th percentile: 45 µg/m^3 1997: 90th percentile: 50 µg/m^3 residential: Whitney Pier Fire Stn., Sydney 1994: 90th percentile: 52 µg/m^3 1997: 90th percentile: 65 µg/m^3 residential: South St., Glace Bay 1994: 95th percentile: 32 µg/m^3 commercial: York Street, Fredericton 1994: 90th percentile: 34 µg/m^3	120 µg/m^3 (NBDOE, 1997)
110 Charlotte Street	1994: 50th percentile: 26 µg/m^3 1994: 90th percentile: 47 µg/m^3 1997: 90th percentile: 77 µg/m^3		

Table 5-19 Comparison of TSP Ambient Levels in Saint John to Urban Background and Guidelines

Location	Ambient	Background	Guideline(s)
Annual averaging time			
Forest Hills	1994: geomean ± SD: 20 ± 16 μg/m³ 1997: geomean ± SD: 23 ± 2 μg/m³	commercial: 254 Water Street, St. John's 1994: geomean ± SD: 20 ± 1.7 μg/m³ 1997: geomean ± SD: 20 ± 1.5 μg/m³ commercial: 56 Fitzroy St., Charlottetown 1994: geomean ± SD: 16 ± 1.4 μg/m³ commercial: Technical University of NS 1994: geomean ± SD: 24 ± 1.5 μg/m³ 1997: geomean ± SD: 24 ± 1.5 μg/m³ residential: Dalhousie University, Halifax 1994: geomean ± SD: 16 ± 1.5 μg/m³ 1997: geomean ± SD: 15 ± 1.5 μg/m³ industrial: CFB Shearwater, Halifax 1994: geomean ± SD: 13 ± 1.4 μg/m³ 1997: geomean ± SD: 14 ± 1.5 μg/m³ commercial: York Street, Fredericton 1994: geomean ± SD: 21 ± 1.6 μg/m³ County Jail, Sydney, NS 1997: geomean ± SD: 26 ± 1.9 μg/m³	70 μg/m³ (NBDOE, 1997)
110 Charlotte Street	1994: geomean ± SD: 26 ± 1.6 μg/m³ 1997: geomean ± SD: 32 ± 1.8 μg/m³		

[1] 50th and 90th percentile, and geometric mean ± SD values are presented as provided by original data sources (95th percentile values were not available from these sources).

Existing and Future Study Area Predicted Concentrations of TSP

Predicted concentrations of ground-level air concentrations of TSP for the existing and future study area scenarios were based on air dispersion modelling (Stantec, 1999a). The sources of TSP emissions considered included the combined stack emissions from the IOL Refinery, Courtenay Bay Power Plant (CB), Irving Pulp and Paper (IPP), Lantic Sugar Refinery (LS), and the Irving Paper Mill (IP). These emissions data were available for both the current and future scenarios. Stack emissions of TSP under the current scenario were based on existing stack emissions data available for the facilities of interest. With respect to the IOL facility, the stack emissions data reflects an average production rate of approximately 190,000 bbl/day. The stack emissions from the IOL facility for the future scenario were obtained by subtracting the contribution from units that were going to be removed as a result of the upgrade and subsequently adding the potential emissions from those units that were being constructed. Estimations of stack emissions for the new units were obtained from the operating specifications supplied by the equipment manufacturer and thus represent operating conditions under optimum performance. The contribution of TSP from Courtenay Bay Power Plant (CB), Irving Pulp and Paper (IPP), Lantic Sugar Refinery (LS), and the Irving Paper Mill (IP) were assumed to remain constant between the exiting and future scenarios. Wind speeds and direction, precipitation and other local weather conditions were considered using one year of meteorological data which spanned from 1997-1998. All particulate sources modelled were assumed to be combustion-related. Based on an analysis of the Stantec (1999a) data, the ambient air concentrations of TSP are predicted to be greater in the future study area scenario than in the existing study area scenario (see Table 5-20).

Table 5-20 Predicted TSP concentrations for the Existing and Future Study Area Scenarios in Saint John

Location	Existing Study Area Scenario	Future Study Area Scenario	%Change
24-hr averaging time			
Forest Hills	95th percentile: 2.3 μg/m³	95th percentile: 2.6 μg/m³	+ 13%
Champlain Heights	95th percentile: 9.9 μg/m³	95th percentile: 11 μg/m³	+ 11%
Silver Falls	95th percentile: 4.9 μg/m³	95th percentile: 5.6 μg/m³	+ 14%
Annual averaging time			
Forest Hills	geomean ± SD: 0.009 ± 3.743 μg/m³	geomean ± SD: 0.018 ± 4.008 μg/m³	+ 100%
Champlain Heights	geomean ± SD: 0.012 ± 1.872 μg/m³	geomean ± SD: 0.014 ± 2.147 μg/m³	+ 16%
Silver Falls	geomean ± SD: 0.006 ± 0.896 μg/m³	geomean ± SD: 0.007 ± 1.164 μg/m³	+ 17%

Potential Impact of the Ground Level TSP Concentrations for the Future Study Area

Modelling of the TSP stack emissions data indicated that the IOL Refinery contribution to ambient TSP is not expected to increase by more than 14% to 24-hr 95th percentiles, and 100% to annual geometric means, as a result of the upgrade. If other sources of TSP are ignored and it is assumed that the modelled stacks account for all of the ambient TSP, then the maximum percentage increase to the ground level ambient air concentrations measured at the community monitoring stations would be the same as for the future study area scenario.

It is expected that when other sources of TSP are considered, the contribution from the IOL Refinery will decrease and thus the actual increase to ground level ambient air concentrations of TSP would be less than those predicted by the worst-case assumptions outlined above. Using the example of Forest Hills, where a maximum 24 hour ambient ground level air concentration for TSP of 77 $\mu g/m^3$ (90th percentile) was observed (Table 5-19), a 13% increase in this value would equate to 87 $\mu g/m^3$. Since this predicted air concentration is below current air quality guidelines for TSP, no measurable adverse health outcomes would be expected in the community under the future study area scenario. Similarly, the predicted incremental increase in TSP for the annual average in Forest Hills would potentially change the existing concentration of 23 $\mu g/m^3$ (geometric mean) to 46 $\mu g/m^3$. This concentration would also not be expected to result in measurable adverse health outcomes in the community.

5.5 Secondary Reaction Products from Various Air Emissions

5.5.1 Ozone

Urban smog, or more specifically photochemical smog, represents a significant health and property concern in North America. When air concentrations are great enough, this yellow-brown haze seen enveloping densely populated urban areas, significantly reduces the air quality and can cause irritation of the respiratory tract and eyes. In sensitive individuals, it may exacerbate more serious respiratory afflictions such as asthma and emphysema to the point where medical intervention is required for such people. Where the smog drifts from its urban source into rural areas, the ozone component of the smog can also cause significant crop damage via direct toxicity to plants (Bunce, 1991).

The conditions necessary for the development of photochemical smog include:

- NO_2
- non-methane hydrocarbons
- sunlight
- elevated temperatures (>18°C) (Bunce, 1991)

Since the photochemical reactions to produce smog are time dependent, and the time factor depends on various meteorological conditions, smog may form some distance from the sources of environmental pollution.

The IOL Refinery, plus a number of other industrial and community activities, are emission sources for both NO_2 and hydrocarbons in Saint John. Automobile and other vehicular emissions have traditionally been a major contributor to smog in dense urban areas. The emissions from the combustion of fossil fuels creates elevated concentrations of NO which are readily oxidized to NO_2. The NO_2 is photolyzed in the presence of intense sunlight to form ground level ozone which undergoes further photolysis to produce the OH radical. The OH radical reacts quickly with organic substrates such as VOCs, to produce aliphatic aldehydes and organic nitrates, which along with ozone are the primary irritants found in smog. Higher temperatures, and stagnant air such as that during "hot, muggy days" favour a reaction rate which exceeds the rate of dispersion thus leading to the accumulation of these potentially noxious products.

Guidelines for Ozone in Air

The concentration of ozone in air is relatively easy to measure and it correlates well with the severity of episodes of photochemical smog. Even though it is not identified as a stack emission, ozone is monitored as an indicator of urban air pollution and Air Quality Standards (AQS) for ozone have been set by a number of jurisdictions. For evaluation purposes, the existing National Objectives for ground level ozone were adopted. These indicated a 1-hour acceptable level of 82 ppb, a 24-hour acceptable value of 25 ppb, and an acceptable annual limit of 15 ppb (NB DOE, 1999b).

Background Ozone Levels in Air

In non-impacted or "clean" air, ozone is found at concentrations typically ranging from 20 to 50 ppb, with the values providing for both diurnal and seasonal variation (Logan, 1985). Air monitoring data for a number of urban and rural locations in Newfoundland, Prince Edward Island and Nova Scotia are provided in Table 5-21. Yarmouth, NS, had the highest levels of ozone with an annual average of 32 (S.D. of 23) ppb which is well within the range of background levels indicated above. A 24-hour maximum was recorded at 70 ppb. All of the locations presented in Table 5-21 had maximum 24 hour levels which exceeded the 24 hour National Air Quality Objective by 1.5 to 3-fold. Similarly, where data were sufficient, these cities showed annual mean ozone concentrations which slightly exceeded the annual National Air Quality Objective by 1 to 2-fold.

Table 5-21 Air Monitoring Ozone Data (in ppb) for 1994 for Locations in the Maritimes (from Environment Canada, 1997)

Location	Minimum (24-hr)	Mean Annual (s.d.)	Maximum (24-hr)
St. John's, NFLD	2	15 (8)	42
Cormack, NFLD	22	Insufficient Data Available	37
North Cape, PEI	14	Insufficient Data Available	64
Halifax (CFB), NS	4	24 (11)	70
Halifax (Barrington), NS	3	19 (10)	56
Aylesford Mountain, NS	0	Insufficient Data Available	64
Yarmouth, NS	7	32 (12)	70

Notes: s.d = standard deviation; The locations of Cormack, Nfld, North Cape, PEI, and Aylesford Mountain, NS had insufficient data available to calculate an annual mean ozone concentration.

Ground Level Ambient Concentration of Ozone in the Air of Saint John, NB

Ambient ground level ozone concentrations within Saint John, NB, were obtained from the National Air Pollution Surveillance (NAPS) Network Annual Summaries which are compiled by Environment Canada (1997) and from the New Brunswick Department of the Environment (NB DOE, 1999b). Annual data are summarized in Table 5-22.

No exceedances of the 1-hour National ozone objective of 82 ppb occurred in Forrest Hills in 1996 or 1997 (NB DOE, 1999b).

Average annual ozone concentrations were available for the Forest Hills area from 1980 to 1996. In order to provide a reasonable representation of current ambient ozone levels in Saint John, data from 1980 to 1989 were omitted. These annual averages (ranging from 16 to 26 ppb) exceed the National objectives for ground-level ozone but are well within the range of ozone concentrations measured at the urban and rural maritime background sites (See Table 5-21). In addition, these annual averages indicate a relatively good level of air quality since "non-impacted areas have ozone levels typically between 20 to 50 ppb while heavily polluted areas typically have annual average ozone concentrations that range from 100 to 500 ppb" (Logan, 1985).

Using the reported standard deviations, the upper 95th percentiles were calculated for each annual average in order to provide an estimate of the upper range of the 24-hour ozone levels for Saint John (Table 5-22). Thus 95% of the time the 24-hour ozone levels were below these values. The 95th percentiles for 1990 to 1996 ranged from 33 to 51 ppb. The 24-hour limit is 25 ppb and thus all of the calculated values exceeded this, however, these values do fall within the range of 24-hour maximums for other maritime cities and are also within the range considered normal for "un-impacted" areas. Areas in southern New Brunswick have also experienced ozone exceedances but these have been attributed to long range transport of air pollutants (NB DOE, 1999b).

Table 5-22 24-Hour Air Monitoring Ozone Data (in ppb) from 1990 to 1996 for the Forest Hills Area of Saint John, NB (from Environment Canada, 1997)

Year	Annual Average (S.D.)	95th Percentile (Log normal)
1990	26 (12)	49
1991	24 (14)	51
1992	16 (9)	33
1993	23 (10)	42
1994	21 (10)	40
1995	23 (10)	42
1996	26 (11)	47

The IOL Refinery Upgrade and Photochemical Smog in Saint John, NB

Emissions resulting from the upgrade of the IOL Refinery would not be expected to significantly change the occurrence of photochemical smog in Saint John, NB. Predicting the levels of photochemical smog, or more specifically the peak levels of ground-level ozone, require consideration of both the concentrations of VOCs as well as NOx in the air. With respect to VOCs, the total amount emitted from the IOL Refinery is not predicted to undergo significant changes as a result of the upgrade. As discussed in Section 5.2 regarding VOCs, relationships developed by CPPI and Environment Canada (1988), show that the production volume of a refinery is correlated with the potential quantities of fugitive hydrocarbon emissions. IOL has indicated that the upgrade project is focussed on increased production efficiency and higher quality products with no intentions to increase production volumes. Therefore, fugitive emissions of total hydrocarbons, of which VOCs are a component, would not be expected to change. In fact, IOL has adopted an aggressive program to reduce fugitive hydrocarbon emissions and thus a reduction of VOC emissions from fugitive sources is more likely.

With respect to NOx, modelling of NOx stack emissions, in order to derive future ground level air concentrations, indicated that NOx is expected to increase by 28% (at the stack) through the future study area scenario (Section 5.3.2). Estimated air concentration increases at ground level are predicted to range from 14 to 18.3% (Section 5.3.2). Based on this information, and given the numerous other sources of NOx including other industries, various residential activities, automotive and other vehicular emissions and long range transport of pollution, the actual contribution of the refinery to the ground level ambient concentrations of NO_x in the community and surrounding areas would be less than the 28% predicted at the stack in the future study area scenario. It is considered unlikely that the estimated change at ground level (14 to 18.3% increase) would significantly impact on the production of ground level ozone and the subsequent accumulation of photochemical smog in the Saint John region. This conclusion is based on the observation that current measured NO_2 concentrations exhibit a variability of +/- 100% (Table 5-11), and therefore an increase of 14 to 18% will not significantly change the mean. As a result of this, adverse health outcomes would not be expected to change significantly over current conditions.

5.5.2 Acid Aerosols

Suspended particulate matter includes a wide range of different sized particles which may be airborne for distances of several kilometres to several thousands of kilometres from the emissions source. Concern with regard to human health is generally focussed on those particles which are small enough to be respirable (*i.e.*, those which can enter the lungs and alveoli during normal breathing, generally particles less than 10 microns in mean aerodynamic diameter or MADD).

Although some believe that the mere physical presence of respirable particulate matter in air may pose a health concern, there is also abundant evidence indicating the importance of considering the various chemical components that are associated with or bound to the particulate matter. The chemical composition of the particulate matter determines the specific nature of the potential toxic effects that may occur in the respiratory system. The composition of particulate matter varies depending on the emission source (*i.e.*, particulate matter can be formed from a wide variety of physical and chemical processes, and as a result of both natural and anthropogenic processes).

"Fine" particulate matter (less than 2.5 microns in aerodynamic diameter) is derived directly from materials that condense in ambient air following incomplete combustion processes (for a comparison of local particulate concentrations to guidelines refer to Section 5.4). Fine particulate matter may also be formed following reactions of precursor gases (such as oxides of sulphur or nitrogen) with various other airborne gases or particles (*e.g.*, VOCs, ammonia). There are many sources of such precursors from various human activities and from natural sources.

Gaseous reactions of sulphur dioxide or nitrogen dioxide with hydroxyl (OH^-) groups (these are highly reactive chemical species that occur naturally in air), result in the formation of sulphuric and nitric acid. Dissolution or dissolving of sulphur and nitrogen oxides in airborne water droplets (*e.g.*, fog or cloud) and reaction with ozone, hydrogen peroxide or even oxygen (if a catalyst is present) can result in the formation of sulphates and sulphuric acid, or nitrates and nitric acid. These various acids and salts remain as particulate matter when the water in the aerosols evaporates in the atmosphere. The presence of ozone in sea salt aerosols enhances the formation of sulphuric acid in coastal areas. The main components of fine particulate matter reflect these sources, and include sulphates, ammonium, and hydrogen ions.

"Coarse" particulate matter (greater than 2.5 microns and less than 10 microns) can also arise from various human activities, but is also derived from the breakdown and atmospheric suspension of crustal materials by natural wind erosion or through human activities (*e.g.*, stirring up soils and dusts). Therefore, coarse particulate matter is composed mainly of aluminum, silicon, magnesium and iron.

The presence of sulphate in coarse and fine particulate matter is enhanced by the presence of high humidity (*e.g.*, fog), and the presence of sodium chloride particles (*e.g.*, from ocean spray), as this provides a mechanism for the growth of fine particles through coagulation or condensation to sizes exceeding 1 micron (US EPA, 1996). It has been reported that cloud phase production of sulphates from sulphur dioxides can contribute significantly to overall coarse particulate matter mass.

Deposition of particulate matter is dependent on the size of the particles. Coarse particles tend to undergo dry deposition, mainly through gravitational settling, and can remain airborne for distances up to tens of kilometres from the emissions source over a period of minutes to hours. Fine particles are much less affected by dry deposition processes, and tend to mainly undergo wet deposition, relying on coagulation and/or condensation processes with moisture and entry into cloud droplets in order to deposit via precipitation. Fine particles may travel hundreds or thousands of kilometres, and can remain airborne for days to weeks. Therefore, reactions involving fine particles can occur over relatively long time periods, and their impacts can be at considerable distances from their source of production. These are the particles involved in long range transport of air pollutants.

The information summarized above demonstrates that particulate matter may contain acidic components, including sulphuric acid, through both direct and indirect mechanisms. Aerosol acidity generally refers to actual acid dissociation and hydrogen ion availability, and may be composed of particulate acidity (sulphuric acid, ammonium bisulphate) and gaseous acidity (nitric and nitrous acids, hydrochloric acid) (US EPA, 1996). Conditions of high humidity can result in greater dissociation of hydrogen ions, leading to greater aerosol acidity.

The acidity of sulphate aerosols may be neutralized or buffered by the presence of ammonia (NH_3^+), which will react to form ammonium bisulphate and ammonium sulphate, (US EPA, 1996). Other buffering systems (*e.g.*, sodium bicarbonate or sodium carbonate, various protein buffers) would be expected to act in a similar fashion. As the reaction products following buffering are much less irritating than the acidic form of the substances, the interaction of acid aerosols with buffering agents provides a mechanism for neutralizing acid aerosols and preventing or minimizing adverse effects on biological systems. Ammonia, sodium salts and various proteins are common buffering systems in biological tissues (*e.g.*, the lining of the lung), and are also present in the environment from a variety of sources, including natural, industrial and agricultural sources. It is notable that the buffering activity of ammonia is generally reduced near or over the ocean due to lower ambient concentrations of ammonia in coastal and marine environments (US EPA, 1996).

The Canadian Acid Aerosol Measurement Program (CAAMP), a joint effort of Environment Canada's Atmospheric Environment Service, the Environmental Protection Service, and the Air Quality Health Effects Research Section of Health Canada, has studied the health effects of acid aerosols since 1992. The key objectives of CAAMP are to: i) collect data on fine particle acidity and fine particle mass in the fine and coarse mode at a variety of Canadian locations, including Saint John; ii) determine annual and seasonal averages, peak levels (12-24 h) and temporal variability of particle acidity and fine and coarse masses; iii) estimate exposure of Canadian population to fine particle acidity to assess the significance of the results of ongoing health effects research, and to ensure that data are appropriate for use in future health studies (Brook, 1994).

Potential Health Effects of Acid Aerosols

As mentioned, the interaction of acid aerosols with buffering agents provides a mechanism for neutralizing acid aerosols and preventing or minimizing adverse effects on biological systems, including human tissues. Following inhalation of sulphate aerosols into the lung, Holma (1985) observed that concentrations up to 1,500 µg/m^3 can be neutralized through reaction with ammonia and sodium buffering systems naturally present in the mucous/sputum and airways of the respiratory system. It was suggested that individuals with compromised respiratory systems, such as asthmatics who tend to have sputum with lower pH values, may be less capable of neutralizing sulphate aerosols and thus be more susceptible to irritation effects (Holma,1985). For such reasons, exposure criteria for acid aerosols are established to be protective of these types of sensitive sub-populations. Since there is also ammonia naturally present on the skin, similar neutralization reactions would be expected to occur, which would prevent or minimize the potential adverse effects resulting from dermal exposure to acid aerosols.

As the composition of acid aerosols can vary, it is difficult to establish the cause of potential adverse health effects in exposed populations. In general, the sulphate and sulphuric acid components of acid aerosols are considered to have the greatest relative contribution to potential adverse health effects than the other components. For example, nitrates have been associated with a lack of significant health effects for short term exposures of less than 1000 µg/m^3 for most receptors (FPWGAQOG, 1997). Sulphates tend to be more active in causing irritation and altered respiratory function, although a wide range of inter-individual variability has been reported. In individuals without respiratory tract disorders, no effects on airway function and alveolar inflammatory response have been observed following acute exposures to concentrations of up to 1000 µg/m^3 (Utell *et al.*, 1984). On the other hand, Spektor *et al.*, (1989) reported a slowing of mucociliary clearance functions of the lung at airborne acid aerosol concentrations in the range of 100 µg/m^3. The US EPA (1996) concluded that sulphates had no adverse respiratory effects on healthy subjects at airborne concentrations up to 500 µg/m^3, and had no consistent impacts at concentrations up to 1000 µg/m^3 for 4 hour exposure periods.

The asthmatic population, especially adolescents, is more susceptible to the impacts of acidic sulphates aerosols than are individuals without such disease states. In asthmatics, changes in airway function has been reported at concentrations above 200 µg/m^3 for acute exposures, and airway flow rates were reported to be decreased following 2 hours of exposure to 100 µg/m^3 (Utell *et al.*, 1983). Several studies have been conducted to examine asthmatic adolescents, who appear to be more susceptible to the effects of acid aerosols. Koenig *et al.* (1989) observed minor decreases in forced expiratory volumes, but no changes in airway resistance, following 30 minutes of exposure to 68 µg/m^3 (mouthpiece exposure). Hanley *et al.* (1992) observed alterations in several lung parameters in adolescent asthmatics exposed to 51 µg/m^3 for 30 minutes(mouthpiece exposure). In a subsequent study, Koenig *et al.* (1992) observed respiratory function in adolescent asthmatics exposed to 35 or 70 µg/m^3 for 40 or 90 minutes. Although minor changes in respiratory functions were observed at 35 µg/m^3 for 40 minutes, there were no significant changes observed at 70 µg/m^3 for 90 minutes.

U.S. EPA (1996) reviewed this study, and noting the lack of clear dose-response, concluded that the results were insufficient to demonstrate convincing effects at these exposure levels. Indeed, Avol *et al.*, (1990) did not observe measurable effects on respiratory function in asthmatic adolescents exposed to acidic aerosol concentrations of 46 µg/m^3 for 30 minutes. This study was conducted in an exposure chamber, as opposed to using mouthpiece exposures, which would allow both oral and nasal exposures, and which would be similar to that expected to occur in the environment. These authors suggested that certain subgroups within the asthmatic population may be more susceptible to sulphuric acid aerosols, given the observation of a small fraction of subjects experiencing bronchoconstriction in the high dose group (134 µg/m^3). In comparison, elderly asthmatics were without impacts on airway resistance at concentrations up to 70 µg/m^3 (40 minutes) (Koenig *et al.*, 1993).

There has been some concern expressed about the potential effects of fog-borne sulphuric acid on human health. As the particle (or droplet) sizes in fog tend to be 10 µm or larger (Hackney *et al.*, 1985), such particles would not be likely to enter the lower parts of the respiratory system. Hackney *et al.*, (1989) reported that at droplet sizes of 10 µm, 1 hour exposures to sulphuric acid aerosols up to 2000 µg/m^3 had no effect on healthy and asthmatic subjects, whereas significant effects on lung expiratory function were observed in asthmatics at the same concentrations when droplet sizes were 0.9 µm. Linn *et al.*, (1989) however, observed a greater irritant effect of sulphuric acid fog on the respiratory system of both healthy and asthmatic subjects with fog droplet sizes in the range of 10 to 20 µm in comparison to effects at droplet sizes of 1 µm. Avol *et al.*, (1988) also studied the effects of sulphuric acid fog and found only minimal impacts on pulmonary function at concentrations of 2,000 µg/m^3 (for 1 hour, at 1 week intervals). Particle size was not reported in this study.

The longer term impacts of sulphates on humans has been studied through epidemiological studies of populations exposed through smog incidences, *etc.* A thorough review of these studies was conducted by Utell and Renzi (1998), who concluded that the available epidemiological data are inconclusive with respect to relating specific health effects to exposures to sulphate particulate matter.

Utell *et al.*, (1983) specifically studied the mechanism for the respiratory effects of sulphates in humans and concluded that acidity was the causative factor, rather than the sulphate ion itself. Similarly, Schlesinger (1989) reported decreased lung clearance in rabbits exposed to sulphuric acid aerosols, with the decrement attributed to exposure concentration, duration and acidity. This conclusion is supported by the mitigative effects of ammonia in the sputum, which neutralizes the acidity and decreases the impact (US EPA, 1996), as discussed above. This mechanism also provides a possible explanation for the increased susceptibility of asthmatics who tend to have less buffering capacity in their sputum.

Estimated Air Quality Guidelines for Acid Aerosols

In determining an air quality guideline for acid aerosols, it is appropriate to consider the specific chemicals of concern: sulphuric acid, sulphates and their reaction products with ammonia. There are presently no air quality criteria available for ammonium sulphate or bisulphate, either for protection of the general public or for occupational exposures. This is likely the result of numerous observations that these chemicals are not potent irritants to biological tissues.

The American Conference of Governmental Industrial Hygienists (ACGIH, 1998a,b) has adopted a threshold limit value (TLV) for occupational exposures to sulphuric acid of 1,000 $\mu g/m^3$ for an 8 hour day, 5 days per week, based on irritation and pulmonary lung function effects. To ensure avoidance of irritant respiratory effects in those exposed continuously, the ACGIH TLV can be converted to a limit of 240 $\mu g/m^3$ for individuals exposed 24 hours per day, 7 days per week (*i.e.*, 1,000 $\mu g/m^3$ x [8/24] x [5/7] = 240 $\mu g/m^3$). To ensure protection of the general public, an additional "safety" factor of 100 can be applied to this value [*i.e.*, 10-fold for susceptible individuals and 10-fold to account for the fact that occupational limits are designed to protect workers who may be in a better state of fitness than the general public (known as the "healthy worker" effect)]. Thus, the 240 $\mu g/m^3$ limit translates into a conservative air quality limit of 2.4 $\mu g/m^3$ for sulphuric acid aerosols.

As sulphates tend to be among the primary components of $PM_{2.5}$, an alternative air quality guideline for acid aerosols may be derived based on the regulatory limit for $PM_{2.5}$ (*i.e.*, 25 $\mu g/m^3$) It could be conservatively assumed that the limit for $PM_{2.5}$ is based on the health effects of sulphates and resulting acidic particulate matter, and thus a limit for sulphates could be derived based on the relationship between concentrations of airborne sulphates and $PM_{2.5}$, as described below. Using the relationship observed for Atlantic Canada (FPWGAQOG, 1997), the air quality guideline for $PM_{2.5}$ can be converted into a guideline for sulphate, as follows: $[SO_4^{2-}] = -0.33 + 0.37*[PM_{2.5}]$. Thus, the regulatory guideline value of 25 $\mu g/m^3$ for $PM_{2.5}$ can be converted to a guideline value for sulphates of 8.9 $\mu g/m^3$.

Perhaps the most appropriate source of an exposure limit is the human clinical studies of impacts on the respiratory tract following controlled exposures to acid aerosols. As discussed above, Avol *et al.* (1990), using an exposure chamber, observed no adverse effects in a susceptible sub-population (adolescent asthmatics) following exposure to acid aerosol concentrations of 46 $\mu g/m^3$ for 30 minutes. With the application of a 10-fold safety factor for protection over longer term exposures, this would yield a guideline of 4.6 $\mu g/m^3$.

Based on the above data, a provisional air guideline for sulphuric acid aerosols between 2.4 and 8.9 $\mu g/m^3$ would appear reasonable. Based on information on asthmatics, it was considered most appropriate to use the air quality guideline of 4.6 $\mu g/m^3$ in the characterization of potential adverse health effects from sulphuric acid aerosols, because this value is based on measured clinical data rather than theoretical calculations. This provisional reference concentration has not been endorsed by any specific regulatory agency; however, it is considered to be sufficiently conservative to provide protection for the community.

Estimation of Ambient Concentrations of Sulphate

While some data on sulphates were available for Saint John for 1992 to 1993 (Brooks, 1994), there were no recent data available regarding concentrations of acid aerosols or sulphates measured at the monitoring stations near the IOL Refinery. There were however, particulate matter data (total suspended particulate matter) available from which concentrations of $PM_{2.5}$ were calculated using the following relationship:

$$PM_{2.5} = 10^{(0.636 \times \log TSP)} \text{ (HC/EC, 1999)}$$

In addition, measured $PM_{2.5}$ background data were available for several locations (St. John's, Halifax, Dartmouth and Kejimkujik National Park (HC/EC, 1999)). These data were used together with the relationship between $PM_{2.5}$ and sulphate, which has been studied (FPWGAQOG, 1997) for various monitoring locations across Canada, and a linear regression relating concentrations of sulphate to that of $PM_{2.5}$ for sites in Atlantic Canada (Saint John, Halifax, Dartmouth, Kejimkujik) indicate the following relationship:

$$[SO_4^{2-}] = -0.33 + 0.37*[PM_{2.5}]$$

Using this relationship, the concentrations of sulphate were calculated for the ambient air monitoring sites in the communities around the IOL Refinery, and are presented in Table 5-24. While measured sulphate concentrations for Saint John were available in a Canadian Acid Aerosols Measurement Program report (Brook, 1994), these data were collected from 1992 to 1993 at one location only (Forest Hills) and were not considered representative of current conditions in East Saint John. For example, the maximum $PM_{2.5}$ concentration reported for 1992-1993 was as much as 3-fold higher than reported concentrations in 1994 or from 1984-1995 (see Table 5-24).

Table 5-24 Estimated 24 Hour Sample Concentrations of Sulphate (µg/m³) based on the Relationship of Sulphate to $PM_{2.5}$

Location		PM 2.5 Concentration	Estimated Sulphate Concentration
Existing Ambient and Reference Locations (from Table 5-17)			
110 Charlotte Street, Saint John	1994 maximum	12.2	4.18
Forest Hills, Saint John	1997 95th percentile	19	6.7
Kejimkujik National Park	rural 90th percentile	13.6	4.70
Duckworth/Ordnance, St. John's	urban 90th percentile	18	6.33
NS Techn. U., Halifax	urban 90th percentile	25	8.92
1657 Barrington St, Halifax	urban 90th percentile	15.1	5.26
Harbour View School, Dartmouth	urban 90th percentile	10.9	3.7
Estimated Contribution from Existing Study Area Concentrations (Stantec, 1999a)			
Forest Hills	95th percentile	1.7	0.3
Champlain Heights	95th percentile	4.3	1.26
Silver Falls	95th percentile	2.8	0.71
Estimated Contribution from Future Study Area Concentrations (Stantec, 1999a)			
Forest Hills	95th percentile	1.8	0.34
Champlain Heights	95th percentile	4.5	1.34
Silver Falls	95th percentile	3	0.78

Risk Characterization

A comparison of the provisional air quality guideline of 4.6 µg/m^3 with the maximum and 95th percentile concentrations of sulphate for existing ambient and reference locations indicates that there are exceedences of this provisional guideline at several locations. The provisional guideline was exceeded at Forest Hills. This indicates that a portion of the population most susceptible to the irritating effects of acid aerosols might be negatively impacted (on a short-term basis) during times when the estimated concentrations exceed the provisional guideline. However, such responses, although undesirable, would likely be of short duration and at infrequent intervals, and would not be expected to result in chronic health outcomes.

The incremental sulphate concentrations predicted for the current and future emission rates (existing and future study area scenarios) are well below the conservative provisional guideline developed above. The predicted increase in contribution to acid aerosols in ambient air from refinery emissions as a result of the facility upgrade was minimal (incremental concentrations associated with the future study area scenario, were 6 to 13% greater than those associated with the existing study area scenario). Given that the ambient and reference concentrations of particulate in Saint John range from 7 to 19 µg/m^3 (Table 5-17), the incremental contribution of the future operations of the IOL facility would result in acid aerosol concentration increases of about 1 to 4% (based on the equation used to derive the sulphate concentrations from $PM_{2.5}$). Therefore, the predicted change in concentrations based on the future study area scenario would not likely have measurable adverse outcomes on public health in the community.

5.6 Additional Exposure Pathways

5.6.1 Potential Exposure from Swimming in Nearby Water Bodies

Some residents were interested in knowing whether there was any possibility for air emissions associated with the refinery upgrade to pose public health concerns to individuals who swim in water bodies in the general vicinity of the IOL Refinery.

Exposure to chemicals in local water bodies could result from dermal contact with substances in water, accidental ingestion of pond surface water, or dermal contact with sediments. Since no surface water or sediment chemical data were available for near-by water bodies, quantitative predictions of possible exposure from these sources was not possible. Several qualitative factors of relevance to swimming in water bodies within the vicinity of the refinery are discussed below to provide perspective on this issue.

- Due to seasonal temperature changes, swimming would likely occur only during the summer months; therefore exposures would not be continuous.

- Based on our experience at other locations, unless there are unusual circumstances (*e.g.*, direct contact with contamination of sediments from conditions such as a landfill, *etc.*) exposures to substances from swimming tend to be insignificant, compared to those occurring from other pathways (*e.g.*, air inhalation, vegetable consumption, accidental soil ingestion).

- Some chemical emissions from the upgraded refinery will be decreased over that which is presently being emitted (*e.g.*, sulfur dioxide).

- Many of the chemicals of potential concern associated with the refinery upgrade are volatile in nature (*e.g.*, VOC's) and would be expected to break down quickly as indicated by short air and surface water half-lives (Howard *et al.*, 1991). In addition, these chemicals would not be expected to accumulate in sediments due to their low log Kow values (octanol water partition coefficient) (Howard *et al.*, 1991). VOCs (*i.e.*, benzene, toluene, ethylbenzene and xylene) were not detected in a recent analysis of East Saint John surface waters (*i.e.*, Latimer Lake intake, Lilly Lake, Red Head Marsh, Silver Falls Headpond, Little River hatchery)(NB DOE, 1998). Therefore, future exposure to these chemicals via swimming, as a result of the upgrade, would not be expected to be measurable.

- PAHs are generally non-volatile, water insoluble and lipophilic which would be expected to associate with sediments rather than surface waters. PAHs also have longer half lives than the VOCs (Howard *et al.*, 1991). However, dermal bioavailability of PAHs is low, therefore exposure to PAHs via swimming would not be expected to be measurable. In addition, PAHs were not detected in a recent analysis of East Saint John surface waters (*i.e.*, Latimer Lake intake, Lilly Lake, Red Head Marsh, Silver Falls Headpond, Little River hatchery)(NB DOE, 1998).

In summary, exposure to chemicals of potential concern from swimming in local water bodies is expected to be of minor significance and would not be expected to measurably increase as a result of the refinery upgrade.

5.6.2 Ingestion of Fish from Nearby Water Bodies

Concerns have been raised by local residents regarding the possibility of emissions associated with the refinery upgrade accumulating in fish from nearby water bodies. No quantitative data were available on surface water, sediment, or fish tissue concentrations of any of the emissions included in this assessment. Therefore, a qualitative review of the nature and concentrations of the substances being released, and the potential degree of chemical exposure residents could be obtaining by ingesting aquatic life from nearby water bodies was conducted.

A major factor to be considered when addressing the consumption of aquatic life as an exposure pathway is the propensity of the substances to bioaccumulate and/or biomagnify (*i.e.*, the accumulation of chemicals in body tissues internally and up the food chain via the diet). These factors can result in the elevation of concentrations of substances in aquatic life, resulting in significant exposures to the top consumers, such as residents consuming fish from local water bodies.

Based on their physical/chemical properties, none of the chemicals of potential concern, have the potential to biomagnify. While fish may absorb PAHs, these chemicals are rapidly metabolized and eliminated (EAG, 1990). Therefore, the potential community exposures to chemicals of potential concern as a result of the refinery upgrade are considered to be negligible. In addition, as previously mentioned, PAHs and VOCs (*i.e.*, benzene, toluene, ethylbenzene and xylene) were not detected in a recent analysis of East Saint John surface waters (*i.e.*, Latimer Lake intake, Lilly Lake, Red Head Marsh, Silver Falls Headpond, Little River hatchery)(NB DOE, 1998).

Another important factor to consider is the amount of fish from local waters that is used as a food source. Given the relatively small size of the water bodies in the vicinity of the facility and the relatively varied diet of a typical person, it is unlikely that a significant proportion of a resident's diet would come from the consumption of locally caught fish.

In summary, exposure to chemicals of potential concern via the ingestion of fish from local water bodies is expected to be of minor significance and would not be expected to increase as a result of the refinery upgrade.

5.6.3 Ingestion of Game Meat from the Vicinity of the Refinery

As certain types of chemicals present in air, water and soils may result in exposures to game animals, community members were interested in knowing whether emissions associated with the IOL Refinery Upgrade could result in the accumulation of the chemicals of potential concern in game species, and whether this could lead to the development of adverse public health effects in individuals consuming this meat.

As Saint John is an urban centre, hunting of game animals within city limits would occur to only a limited extent and within areas which are not heavily populated. Thus, most hunting by Saint John residents would likely occur in areas inside or outside the city at distances with much lower air concentrations of emissions due to dilution in the atmosphere, degradation by atmospheric chemical reactions, and deposition at locations nearer the IOL Refinery and other industries. For this reason, and since no data on chemical contaminant levels in local game species were identified, ingestion of game meat was assessed in a qualitative manner. Furthermore, the lack of soil, water and air data for the chemicals of potential concern in areas where hunting is permitted precluded estimates of game animal tissue concentrations or body burdens through quantitative mathematical modelling techniques.

Similar to the fish consumption exposure pathway, a major factor to be considered is the ability of the chemicals of potential concern to bioaccumulate and biomagnify, which may result in elevated exposures to top consumers, such as local hunters and their families. As indicated in Section 6.6.2, all chemicals of potential concern have a negligible or limited potential to bioaccumulate and biomagnify. While PAHs may accumulate in some animals, most game species are able to quickly metabolize and eliminate these chemicals. Thus, it is unlikely that significant PAH exposures would result from the consumption of game animals. Furthermore, given the relatively varied diet of East Saint John residents, it is unlikely that a significant portion of their diet would come from the consumption of local game meat.

In summary, exposure to chemicals of potential concern via the ingestion of game meat is expected to be of minor significance and would not be expected to increase as a result of the IOL Refinery Upgrade.

5.6.4 Ingestion of Chemicals on Snow

During the public consultation, concerns were voiced regarding the potential health effects resulting from the short term exposure of children to chemicals in local snow (*i.e.*, via ingestion of snow). As no data on concentrations of the chemicals of potential concern in Saint John area snow were available to conduct a quantitative evaluation of this short term exposure pathway, a qualitative assessment was conducted.

Air emissions may accumulate in snow in two main ways: i) atmospheric scavenging of particles and gases by snow flakes or crystals during snowfall, ii) wet (*i.e.*, rain, fog) or dry deposition of emissions onto ground snow. Snow is an important sink for a number of atmospheric pollutants, as snow precipitation is an efficient collector (or scavenger) of inorganic and organic pollutants from the air. Snow is widely recognized as having a much higher (approximately 5 times higher) atmospheric scavenging efficiency than rain, due to the greater size and surface area of snowflakes and snow crystals (Sparmacher *et al.*, 1993). While the specific surface area of a snowflake is uncertain, it is believed to range from <0.1 to >1.0 m^2/g (Hoff *et al.*, 1995). A snow flake is essentially an aggregate of snow crystals, where the geometry of the crystals allows them to cling together after they have collided in the atmosphere (Mitra *et al.*, 1990a). It has been shown in experiments with aerosol particles that snow flakes display a considerably greater scavenging efficiency than snow crystals, believed to be due to a filtering effect involving the open mesh structure of the snow flakes, which allows air to flow through the falling snowflake, thus enhancing the snowflake's ability to trap small (0.2 to 2 µm) particles (Mitra *et al.*,1990a,b; Lew *et al.*, 1986). Snow crystals and rain drops have lower scavenging efficiencies because atmospheric particles tend to follow the streamlines around the crystals or drops (Mitra *et al.*, 1990a). Below the cloud cover, snow flakes are the predominant form of snow precipitation (Mitra *et al.*, 1990a). Snow scavenging rates are influenced by a number of physical and chemical factors including particle size, snow crystal capacitance, charge, particle size, atmospheric temperature, and relative humidity (Miller, 1990). Due to the complex interactions of these factors, there have been few accurate estimations of snow scavenging rates that account for these major physical-chemical factors (Miller, 1990). Relative humidity appears to be one of the most sensitive factors affecting snow scavenging rates. For example, a modelling study by Miller (1990) reports that a 5% change in relative humidity can affect the snow scavenging rate by as much as an order of magnitude.

A variety of compounds, in particulate, vapour or aerosol form, have been found to be scavenged by falling snow, including metals, PAHs, PCBs, phenols, chlorophenols, and gaseous air pollutants such as sulfur dioxide and nitrogen oxides (Franz and Eisenreich, 1998; Mitra *et al.*, 1990a,b; Viskari *et al.*, 1997; Mindas and Skvarenina, 1995; Hautala *et al.*, 1995; Baisden *et al.*, 1995). In general, there is much less data available on the scavenging of organic chemicals by snow than there is for inorganic chemicals.

In winter, the cold temperatures, combined with a lower intensity of solar radiation can result in high concentrations of gaseous air pollutants (Ettala *et al.*, 1986). Many of these gaseous pollutants (*e.g.*, sulfur dioxide, nitrogen oxides) can readily adsorb onto snow flakes in the atmosphere (Mitra *et al.*, 1990a). Mitra *et al.*, (1990b) found that snow crystals can scavenge sulfur dioxide both by adsorption and during their growth, especially in the presence of hydrogen peroxide where sulfur dioxide can be efficiently scavenged by snow crystals at atmospheric levels in the parts per billion range. Gas scavenging also appears to be an important atmospheric removal mechanism for low molecular weight PAHs; however, there is currently some controversy regarding the relative importance of gas scavenging for these compounds (Wania *et al.*, 1999; Franz and Eisenreich, 1998). Similar to sulfur and nitrogen oxides, PAH air concentrations also tend to be highest in winter due to colder temperatures and low solar irradiation, but also because of the increased burning of fuels and higher traffic volumes in winter (Baek *et al.*, 1991). Generally, high molecular weight PAHs are associated with particles in the atmosphere with more volatile low molecular weight PAHs occurring in a gaseous form (Finlayson-Pitts and Finlayson, 1986). However, in winters, the majority of PAHs tend to occur primarily in the particulate phase (Finlayson-Pitts and Finlayson, 1986; Baek *et al.*, 1991). As snow efficiently scavenges particles from the air, PAHs (especially those with high molecular weights) may be deposited in relatively close proximity to emission sources during snow events (Finlayson-Pitts and Finlayson, 1986). A study by Franz and Eisenreich (1998) found that particle scavenging was the predominant factor contributing to PAH concentrations in snow, relative to vapour scavenging. However, Wania *et al.*, (1999) reported that vapour (or gas) scavenging for low molecular weight PAHs may also be significant. The major process contributing to metal concentrations in snow is particle scavenging, as most metals do not exist in the atmosphere as vapours to any appreciable extent.

Mitra *et al.*, (1990a,b) reported that snow flakes scavenge atmospheric compounds mainly by means of impaction scavenging (*i.e.*, compounds attach to snow crystals via various collision mechanisms, whereas individual snow crystals may scavenge aerosol particles through impaction or nucleation scavenging (*i.e.*, the chemical compounds act as ice-forming nuclei). A number of field studies have indicated that impaction scavenging appears to be the more significant of the two scavenging processes (*e.g.*, Borys *et al.*, 1988; Reynolds, 1983; Raynor and Hayes, 1983). Alternatively, chemicals in the atmosphere may enter water droplets prior to their freezing and becoming snow crystals or may become part of the snow crystals as a result of gases and vapours adsorbing to the surface of the crystals and becoming subsequently built into the crystal lattice structure (Mitra *et al.*, 1990b).

It should also be noted that chemicals may become deposited in snow through means other than snow scavenging. For example, deposition of chemicals onto snow from fog and dry deposition may also be significant (Bergin *et al.*, 1995a,b). It is therefore important to consider all deposition processes when studying the chemical composition of ground snow.

Since the IOL Refiner operates continually, deposition of chemicals of potential concern from the facility onto local snowfall would occur, the extent of which would depend on the prevailing meteorological conditions. However, such exposures would likely be infrequent and of relatively short duration compared to exposures through breathing air, consuming garden produce and accidental ingestion of soils and dusts (these exposure pathways were evaluated for receptors, including the toddler-aged child, in the current health assessment). Furthermore, melting of ground snow and the accumulation of new snowfall would limit exposures to some extent, via the removal of snow-bound chemicals in meltwater, or the burying of chemicals under new snowfall which may contain fewer air contaminants. Finally, the ingestion of snow by children would be relatively small compared to the accidental ingestion of soils by children. Consideration of these factors leads to the conclusion that children are unlikely to be capable of ingesting sufficient amounts of snow to result in chemical exposures that are high enough to result in potential adverse health effects.

5.7 Comments on Other Specific Community Concerns

5.7.1 Predicted Impact of Refinery Upgrade on Noise Levels

While any large industrial facility is likely to generate noise, at levels that may cause periodic complaints from nearby residents, noise from the IOL Refinery does not appear to be the major cause for public complaints. For example, of the 89 direct public calls to the Refinery in 1998, 12 were regarding noise (*i.e.*, 13%)(IOL, 1999a). Of 14 calls relayed to IOL in 1998 by the NB DOE, none were regarding noise. Furthermore, over the period 1995-1998, only about 1% of the more than 5,000 calls logged by the NB DOE 24 Hour Air Quality Response Program pertained to noise complaints (NB DOE, 1999c) (It should be noted that calls to the IOL Refinery and NB DOE may not necessarily reflect all noise complaints as some individuals may call environmental groups, organizations, *etc.*, with their complaints, as opposed to the IOL Refinery or NB DOE). However, community members indicated during public consultation, that the potential increase in noise from the refinery upgrade is a concern. Their concern stems in part, from the "start-up" of a previous upgrade by the refinery where noise levels increased significantly. The issue was however, dealt with by the IOL Refinery and noise levels eventually decreased. The evaluation of noise related to the construction of the IOL Refinery Upgrade, which was of concern to residents, was not part of the scope of this assessment.

While noise levels at or near a source are generally not subject to the effects of environmental variables, the transmission of noise to distances away from the source are influenced by such environmental parameters as air temperature, wind speed and direction, humidity, and topographic factors such as hills, trees, buildings, *etc.* Thus, noise levels measured at distances from their source typically vary by large amounts.

In September of 1998, IOL conducted a baseline noise-level assessment at the residential property boundary nearest to the Refinery property (*i.e.*, the fence line behind the Irving tanks near Creighton Avenue). Instantaneous noise measurements were taken in the early morning (2:00 to 3:00 am) over a period of two weeks (September 16th to 28th). Measurements taken in the early morning are less likely to be influenced by competing noises from traffic and other nearby industries; thus they are more representative of refinery-generated noise levels than measurements taken at other times of the day. Both the mean and median noise level were 57 dBA, with a minimum of 51.8 dBA and a maximum of 64 dBA (IOL, 1999b). The second greatest value was 58.5 dBA.

In addition to noise level monitoring at the nearest residential properties, IOL took pre-construction instantaneous sound measurements along the northern fence line, eastern property line (Grandview Avenue), other residential locations (Champlain Drive, Bayside Drive, Creighton Avenue), and several locations inside the refinery boundaries near its periphery from December 1997 to September 1998 (*i.e.*, IOL, 1999b). These measurements included other ambient noise sources such as traffic, the NB Power generating station, the NB Power substation, the Irving Paper Mill, and the Cement

Plant. Sound levels taken adjacent to existing refinery units in the heart of the Refinery complex ranged from 62.3 to 86.8 dBA. Overall ambient noise levels at the King of Cats construction site (*i.e.*, proposed locations of new units) due to operation of the existing facility ranged from 52 to 68 dBA. All noise measurements taken along Creighton Avenue and Champlain Drive were less than or equal to 50 dBA. Sound measurements taken along the IOL Refinery periphery ranged from 41.1 to 65 dBA.

Ambient pre-construction noise measurements were also taken by the New Brunswick Department of the Environment (NB DOE, 1999d) from October of 1998 to January of 1999 at four locations (*i.e.*, the closest residence to the Refinery property at Champlain Heights, NE corner of the Refinery at Grandview Avenue, the 1st residence on Red Head Road, and the top of Midwood Avenue). Sound pressure levels varied considerably over this monitoring period and were reported to range from 38 to 89.2 dB. Ten minute weighted average sound pressure levels ranged from 45.3 to 73.1 dB (NB DOE, 1999d). NB DOE sound level readings were taken at various times of the day, with the majority of readings taken either between 9:00 and 11:00 pm or between 5:00 and 7:30 am. The higher sound level readings reported by NB DOE generally coincided with reported heavy local traffic. All sound pressure level measurements varied with the prevailing meteorological conditions (*e.g.*, wind speed and direction, cloud cover, precipitation, temperature *etc.*).

There are no New Brunswick regulations or guidelines applicable to noise emissions at this time. However, the Nova Scotia Department of the Environment has established Guidelines for Environmental Noise Measurement (NS DOE, 1990) as follows:

▸ Daytime (7:00 to 19:00)	65 dBA L_{eq}
▸ Evening (19:00 to 23:00)	60 dBA L_{eq}
▸ Night (23:00 to 7:00)	55 dBA L_{eq}
▸ Sundays and Holidays (all day)	55 dBA L_{eq}

The "L_{eq}" denotes an equivalent noise ratio, which is an averaging of sound levels over time, and the dBA represents decibel units with a weighing to account for the normal range of human hearing (the "A").

Noise level data collected by IOL in September of 1998 (*i.e.*, the baseline noise level at the residential property boundary nearest to the Refinery property - the fenceline behind the Irving tanks near Creighton Avenue (IOL, 1999b)) are considered the most relevant data for comparison to guideline values. These data best represent the contribution of the Refinery to ambient noise levels as the data were collected in the early morning (2:00 to 3:00 am). Early morning measurements are less likely to be influenced by noise from traffic and other nearby industries; therefore they are more representative of refinery-generated noise levels than measurements taken at other times of the day.

As the IOL Refinery is a 24 hour operation, noise levels generated by the facility are assumed to be similar regardless of the time of day. The mean and median noise level (57 dBA) recorded at the nearest residential property boundary (*i.e.*, the fenceline behind the Irving tanks near Creighton Avenue) is lower than both the daytime and evening NS DOE guideline values of 65 and 60 dBA. The mean/median measured noise level at the refinery property boundary marginally exceeds the night/holidays NS DOE guideline of 55 dBA. However, as sound measurements were taken at the fenceline, noise levels would be lower at actual residences due to greater distance from the refinery operations, and various interfering factors such as trees and various buildings structures that would attenuate noise levels.

A number of other jurisdictions have developed regulations or guidelines for noise levels which are similar to those of NS DOE (1990). The Alberta Energy Utility Board Permissible Sound Levels range from 40 to 76 dBA, depending on the time of day, distance to heavily travelled roads, and concentration of dwellings. In the U.S., the EPA general guideline for noise levels on properties adjacent to a noise source is 60 to 65 dBA. Regulatory agencies in Maryland and Delaware have developed environmental noise standards for residential areas of 65 dBA (day) and 55 dBA (night). With the exception of the night noise standards for Maryland and Delaware (which are equivalent to the NS DOE night guideline value), the mean and median noise level measured near Creighton Avenue (57 dBA) is below or within the ranges of values specified by these jurisdictions.

As stated in the IOL Application document (IOL, 1998), the location of the new units is such that they are adjacent to existing refinery process units. In addition, all new units have low noise levels built into their design, as it is a project objective of IOL to not increase sound levels in adjacent residential areas. A number of the existing units built in the 1950's were not designed for low noise operation, and thus have higher noise levels due to the design of their fired heater systems (IOL, 1999c). It should be noted that one of these older units (Crude Unit #2) has been demolished and another will be placed on backup status with the upgrade (Crude Unit #1) (IOL, 1999c). Therefore, noise levels following completion of the upgrade are unlikely to exceed baseline noise levels measured in September of 1998, and may even be lower than these levels, due to the demolition of Crude Unit #2 and the relegation to backup status of Crude Unit #1.

No specific details were provided regarding potential changes in noise levels associated with the upgraded refinery with respect to flaring. Flaring is generally necessary only when there is a loss of cooling water, air, power or steam, or other process upsets, and is the means by which hydrocarbon vapours are safely relieved prior to unit shutdown. Flaring noise is essentially a combination of jet noise as the hydrocarbon vapours exit the flare tip, and combustion roar as the hydrocarbon vapours are burned (AGRA, 1998). Flaring noise can also be caused by steam applied to the flare to minimize the size of the flare and its corresponding smoke plume. The IOL Refinery has steam tips that were installed on the flaring equipment in response to public concerns about the size of flares. Sound levels produced by flaring tend to vary considerably, depending on the vapour composition, gas flow rates, and local meteorological conditions. While flaring noise is often a cause of anxiety and annoyance to nearby residents, the noise decreases progressively with time as the hydrocarbon vapours are relieved, and the frequency of occurrence of flaring events is small. No specific details of noise levels during planned startup and shutdown events were available; however it was reported that noise is expected to be minimized by following the detailed procedures designed for the startup/shutdown of each new unit, as well as the use of vent silencers (IOL, 1999c).

In conclusion, since noise levels are not expected to increase above current baseline conditions (an IOL objective of the upgrade project), no adverse impacts related to noise are expected to occur in adjacent residential areas as a result of the upgrade. As stated in the IOL Application document (IOL, 1998), sound level contours at the Refinery fence and in neighbouring residential areas will be established at several times of day before the new units are brought online, and rechecked following the commencement of new unit operation. In the unlikely event that noise levels do increase in some areas, despite the designed-in controls on the new units, sound control equipment such as sound deadening enclosures would help mitigate the problem and should be employed where necessary. Recommendations related to this issue are presented in Section 9.0.

5.7.2 Potential Visual Effects

As part of the terms of reference for the PHRA (DHCS, 1999), potential visual effects as a result of the upgraded to the IOL Refinery were assessed. To conduct this assessment, information on how the completed IOL Upgrade would look from various areas surrounding the refinery, was requested from IOL.

CANTOX ENVIRONMENTAL INC. was provided with a series of photographs from a number of locations around the perimeter of the refinery taken on June 22, 1999 by IOL. From these photographs, the study team requested PDF images of how these areas would look following the Refinery Upgrade for the following locations:

- Creighton Avenue (area affected by the water pipeline and fence)
- Grandview Avenue (middle)
- Champlain Drive
- Loch Lomond Road (Refinery entrance)
- Start of Red Head Road

In early November, the study team was provided with a PDF image of an aerial view of the IOL Refinery Upgrade project looking North (PDF images of other areas were not provided). Current photographs taken from five locations around the project (*i.e.*, Bayside Drive, Red Head Road, bottom of Grandview Avenue, Loch Lomond Road and the middle of Grandview Avenue) were provided to the study team. From the photographs provided, construction of the upgraded units was clearly visible from both the bottom and middle of Grandview Avenue.

A site visit to the area in mid-October revealed that much of the shorter upgraded components are not clearly visible along Grandview Avenue due to the construction of a berm along this road. IOL has indicated that their intention is to seed and plant trees along this berm. Some taller upgraded structures in addition to cranes being used for the upgrade are visible in the photographs provided of Bayside Drive, Red Head Road, and Grandview Avenue. Larger units, such as the RFCCU (Residue Fluid Catalytic Cracking Unit) will be taller than refinery units existing prior to the upgrade (IOL, 1999c) and will clearly be visible to the community once the upgrade is complete. The cranes however, are associated with the construction phase, and would not be a permanent feature of the Upgraded IOL Refinery once construction is completed.

While the refinery is clearly visible from Loch Lomond Road, it is unlikely that a passer-by would be able to determine how this view has changed from the onset of the upgrade construction at this location (based on the photograph provided), possibly with the exception of the RFCCU stack which will be taller than the existing units.

It is difficult to determine specifically how the view planes of nearby residents will be affected following construction as the photographs provided to the study team were taken from an industrial rather than a residential area, and construction has not yet been completed. However, it is clear that some components of the Upgraded Refinery will be visible to the community once construction is completed.

While no photographs were provided for Creighton Avenue or Champlain Drive, a drive around this area in early October by the study team showed that the construction of the water line and fence (which are part of the Upgrade project) has significantly altered the view planes of many residents in this area (particularly Creighton Avenue and York Street) due to the loss of older trees. While the area has been re-vegetated following the waterline construction, it may take some time before vegetation grows to the pre-construction levels.

Due to the lack of availability of future view planes of the IOL Refinery Upgrade from many of the residential areas surrounding the facility, it would be useful to conduct a more detailed assessment of this issue if there is continued public concern.

5.7.3 Predicted Impact of Refinery Upgrade on Night Light Levels

As part of the terms of reference for the PHRA (DHCS, 1999), potential effects as a result of nighttime light levels from the upgraded refinery were required to be assessed. To conduct this assessment, information related to the current and future light levels associated with the refinery was requested from IOL.

Based on information provided by IOL (1999c) all upgrade units will be provided with lighting of similar intensity to existing refining units. When the refinery is viewed from the East, lighting is expected to be similar to current conditions, however; IOL has indicated that the RFCCU (residue fluid catalytic cracking unit) will be taller than existing units. When viewed from the West, lighting on the new units is also expected to be similar to current conditions. When viewed from the South and North, the lighting on the new units will be seen "end on", meaning the lighting will not be directed towards these directions; thus there is expected to be limited visual impact for residents viewing the refinery from a southern or northern location. When the new units are viewed from the industrial park at the corner of Grand View and Bayside Drive, a non-residential area, IOL has reported that light levels are expected to be similar to current light levels from newer units such as the existing alkylation unit (IOL, 1999c). In summary, based on the available data, lighting on the new units is not expected to significantly increase night time light levels above current light levels from the existing refinery units. As such, no adverse impacts on the neighbouring residential areas related to increased night time light levels are expected to occur as a result of the upgrade. Recommendations related to this issue are presented in Section 9.0.

5.7.4 Qualitative Discussion of Odour Impacts Associated with the Refinery Upgrade

Odours believed to originate from the IOL Refinery are a major source of public complaints to both the IOL Refinery and NB DOE. In 1998, 45 of 89 calls to the Refinery concerned odours (50%), as did 13 of 14 calls logged by NB DOE in the same year (IOL, 1999a). Over the period 1995-1998, approximately 41% of the calls logged by the NB DOE 24 Hour Air Quality Response Program pertained to odour complaints (NB DOE, 1999e). It should be noted that odour complaints made to Irving and DOE may not necessarily be attributable solely to the IOL Refinery. As there are many different potential odour sources in East Saint John, it is difficult to separate out emissions from the refinery in isolation of other sources. In addition, calls to the IOL Refinery and NB DOE may not necessarily reflect all odour complaints.

Based on a review of IOL Environmental Concern Forms from January of 1997 to June of 1999 (IOL, 1999d), the major types of odours reported by callers to the IOL Refinery included the following: "strange smells", heavy oily smells, crude odour, fuel oil, gas odour, musty, oily, petroleum-like, water-treatment-like, propane, sour gas, sulfur, burning smell, foul or pungent odours, skunky, "burnt match", "hot engine", and "urine-like". In general, odour control in Saint John, as in most cities, has been difficult to implement as many chemicals have very low odour thresholds, and odour is a subjective concept, in that odours that are extremely objectionable to some may be acceptable to others (Ruth, 1986; Amoore and Hautala, 1983).

Data compiled by the NB DOE during daily odour patrols in 1998 from 12 monitoring locations (or patrol sites) around the IOL Refinery indicated that heavy oil, light oil, and light ends odours were detected on 56%, 62%, and 54% of patrols, respectively (NB DOE, 1999e). In combination, these three odour types were reported to be responsible for 46% of the total odours noted during the patrols. While smoke and water treatment pond odours were also detected frequently (*i.e.*, detected on 27% and 48% of patrols for water treatment pond and smoke, respectively), it is difficult to attribute them to the IOL Refinery as other potential sources of these odours occur nearby (*e.g.*, pulp mill water treatment lagoon, residential chimneys). Hydrocarbon odours were detected most frequently at patrol site 6 (Grandview Avenue adjacent to an auto salvage shop), but were also detected with considerable frequency at patrol sites 4, 5, and 8 (Grandview Avenue at the pulp treatment lagoon; Grandview Avenue at Industrial Drive; school along Champlain Drive). Once again, it should be noted that odours detected at a particular location are not necessarily solely attributable to that location and can be influenced by other sources (for example, some odours may originate from areas which were not included as patrol stations or within the immediate area). Based on odour patrol data collected by NB DOE during the 24 Hour Air Quality Emergency Program, the mean odour index for 1995 to 1997 was 1.7 (between Fair to Good and Fair), while the mean odour index for 1998 was 2.5 (Fair to Poor) (NB DOE, 1999e).

Specific data projections related to the potential odours levels to be expected as a result of the refinery upgrade were unavailable. However, the reduction in the production of Bunker C following the upgrade would be expected to reduce the "heavy oil odours". In addition, the IOL Application document (IOL, 1998) states that potential odour streams associated with the new units will be identified and subjected to detailed engineering review to ensure that they are adequately contained and managed. IOL has indicated this will be accomplished through good engineering design of sealing mechanisms for shafts and stems, plugging and capping vent and drain connections, and hazard and operability review during the design process. Although there are insufficient data available to determine how refinery odours will be impacted by the addition of the new units, based on the information provided to CANTOX ENVIRONMENTAL INC., the likelihood that there would be significant changes from current odour emissions is small, as the new units are generally closed systems.

It should be noted that the Refinery has taken a number of steps in recent years to reduce odour emissions. These steps have included repair and refurbishment of the main sour water tank, cleanup of the equalization pond, sludge removal from the biox pond, closer odour management at the source, and improved vapour leak detection and repair (Murphy *et al.*, 1996). In addition, as discussed in Section 6.2, IOL has adopted an aggressive programme to reduce total fugitive sources of emissions which contribute to odours, as measured by on-site hydrocarbon detection systems (IOL, 1999e).

Recommendations related to potential odours associated with the IOL Refinery Upgrade are presented in Section 9.0.

5.7.5 New Technologies

During the public consultation program, concerns were expressed by several residents regarding whether the new units that are to be built as part of the upgrade have been properly "tested" or "proven". The residents' main concerns were that the new units would not work as expected, and that there would be greater emissions, noise levels, and potential for accidents than presently predicted. Although the issues of new technologies and technology reliability are important, this issue is not directly related to the possible public health aspects of the IOL Refinery Upgrade, and is outside the scope of the health risk assessment. However, since there appeared to be a high level of public concern about this issue, the study team has provided some comments on the issues of new technologies and their reliability, where data were available, with the primary focus of addressing a process whereby these concerns could be addressed in a satisfactory fashion.

Based on the information provided in the Application to Register the Irving Oil Refinery Upgrade Project (*i.e.*, IOL, 1998) and the Approval to Construct and Operate (NB DOE, 1999a), the upgrade will involve construction of several additional process units including, but not limited to:

- Crude Oil Distillation Unit (CDU)
- Residue Fluid Catalytic Cracking Unit (RFCCU)
- Alkylation Unit (AU)
- Sulphuric Acid Regeneration Unit (SARU)
- Sulphur Plant Tail Gas Unit (SPTGU)
- Amine Sulphur Recovery Unit (ASRU)
- Sour Water Stripping Unit (SWSU)

Detailed process descriptions for each of these units can be found in IOL (1998).

To address residents' concerns that these units may not work as expected, information on the performance reliability, or "track record" of these units was requested from IOL. In addition, information provided in the Application to Register the Irving Oil Refinery Upgrade Project (IOL, 1998), as well as information provided by the manufacturer's of these units was reviewed, where available. Further discussion of individual units is provided below. Comments on the reliability of new technologies are provided only for those units or infrastructure for which the study team had data.

- **Crude Oil Distillation Unit (CDU):** The new crude oil distillation unit (CDU) will be quite similar to the refinery's existing #3 CDU, which has operated reliably for 25 years (IOL, 1999c).

- **Residue Fluid Catalytic Cracking Unit (RFCCU)**: The residue fluid catalytic cracking unit (RFCCU) employs the latest proprietary technology for heavy feed processing from Stone and Webster Technology Corporation. Since 1980, Stone and Webster has been a world leader in the application of fluidized catalytic cracking technology to refinery operations. There are presently 19 FCC units in operation as well as 82 revamps or upgrades in various countries, including 5 in the United States (Stone and Webster Engineering and Construction, 1999). Many of these units have been in service for several years and refineries using these units have reported that they are reliable, efficient, and easy to operate. Stone and Webster Engineering and Construction (1999) reported several advantages of their RFCCU over other similar units which included: low maintenance, increased efficiency, ease of startup, operation and shutdown, low coke yield, minimal thermal stresses, longer run-lengths between turnarounds, and increased operating flexibility (Stone and Webster Engineering and Construction, 1999).

  The outlet of the RFCCU is a wet scrubber where an alkali solution will remove particulates and sulphur oxides (IOL, 1998). The same scrubber will also scrub the flue gas from the crude unit fired heaters. The wet scrubber technology is currently employed in three refineries in the United States (IOL, 1999c).

- **Alkylation Unit (AU)**: The new alkylation unit (AU) is essentially a modernized twin of the existing alkylation unit began operation in 1990 (IOL, 1998). IOL indicated that the existing unit has operated reliably for 10 years (IOL, 1999c). The modernization consists of a larger compressor and heat exchangers in the refrigeration circuit (IOL, 1998). This is necessary due to the recent legislation banning the use of freon refrigerants. Replacement refrigerants do not have as pronounced a heat of vapourization advantage as freon refrigerants did; therefore, increased compressor and heat exchange capacity is needed. The new AU will employ the latest proprietary technology from Stratco Inc., a world leader in alkylation technology. Stratco's technology and all the features of the Stratco Contactor Reactor™ are designed to optimize the alkylation reaction. To date, Stratco Inc. has installed over 500 alkylation units around the world, some of which have been in use since the 1940's, and continue to be used today (Stratco, 1999). The new AU will use sulphuric acid as a catalyst (IOL, 1998). The selection of a sulphuric acid catalyst over a hydrofluoric acid (HF) catalyst is more expensive but offers a number of advantages from both a process and environmental safety perspective. These advantages include increased throughput, increased octane, elimination of potential health risks from HF emissions, and no need for costly HF mitigation technology (Stratco, 1999). The sulphuric acid catalytic process is reported to be one of the lowest risk and most environmentally friendly alkylation technologies available (IOL, 1998)

- **Sulphuric Acid Regeneration Unit (SARU)**: The sulphuric acid regeneration unit (SARU) has been indicated to be less proven in refinery applications than other new units (IOL, 1999c). The SARU uses a licensed proprietary technology developed by a Danish company, Haldor Topsoe, known as the Wet gas Sulphuric Acid (WSA) process. This WSA process catalytically regenerates hydrogen sulfide and organic and ammonium-loaded spent sulphuric acid from the alkylation unit into concentrated commercial grade sulphuric acid (Haldor Topsoe, 1999). The WSA process is reported to be a reliable and efficient sulphuric acid regeneration system (>99% recovery)(Haldor Topsoe, 1999). In the event that the SARU comes offline, IOL has indicated that it will revert to its current operation (96% recovery; IOL, 1999f).

Haldor Topsoe has over 20 years of experience in developing environmental technologies such as the WSA process. There are currently over 25 applications of the WSA process at a variety of industrial facilities around the world that are either installed or under design or construction (Haldor Topsoe, 1999). The WSA process has been applied at refineries, coke chemicals plants, viscose fibre plants, gasification plants, and non-ferrous roasters and smelters (Haldor Topsoe, 1999; IOL, 1998).

- **Sulphur Plant Tail Gas Unit (SPTGU)**: This unit employs similar technology to the SARU in that it also uses the proprietary WSA process developed by Haldor Topsoe. Like the SARU, the SPTGU is also relatively uncommon in refinery operations. However, the addition of this unit, along with the SARU, will allow IOL to market commercial grade sulphuric acid that is not needed for reuse in the alkylation units. In the event that the SPTGU ever goes off line, the refinery will revert to its current operation (96% recovery; IOL, 1999f).
- **Amine Sulphur Recovery Unit (ASRU)**: The new ASRU will be a duplicate of an existing unit and will operate in parallel with this unit. This will provide greater capacity for hydrogen sulphide recovery, as well as redundancy and flexibility (IOL, 1998).
- **Sour Water Stripping Unit (SWSU)**: Similar to the duplicate ASRU, the new SWSU will be a duplicate of an existing unit and will operate in parallel with this unit, stripping hydrogen sulphide and ammonia from sour water (IOL, 1998). The new SWSU will provide greater capacity for hydrogen sulphide and ammonia stripping from sour water, as well as redundancy and flexibility (IOL, 1998). In addition, the construction of a duplicate SWSU will improve the reliability of the hydrogen sulphide stripping process.

If continued concern is expressed by the community relating to new technologies for the IOL Refinery Upgrade, additional information could be provided to the community by IOL on this issue. In addition, the program IOL has in place for training staff and bringing new technologies in the upgrade on-line should be communicated to the public.

5.7.6 Upset and Accident Scenarios

While it was not part of the terms of reference for the PHRA to quantitatively assess potential upset conditions (*e.g.*, start-up, shut-down, maintenance, power failures) or accident scenarios, several community members indicated their concern with potential upsets and accidents associated with the upgraded units at the refinery. Since no quantitative data related to upset conditions or accidents were available, an assessment of upset or accident scenarios could not be undertaken.

Recommendations related to conducting an assessment of these issues are presented in Section 9.0.

5.7.7 Flaring

During the public consultation program, a number of residents expressed concerns regarding whether the addition of the new process units would result in increased flaring activity. In addition, some residents were concerned about the chemical composition of such flares.

Although detailed information on the potential for flaring associated with the upgrade was not available, it was indicated that in general, the new units will not increase the amount of flaring; however, more units will have the potential to flare (IOL, 1999f).

Based on information provided to the Study Team (IOL, 1999f), the flaring system employed at the IOL Refinery consists of a network of piping connected at one end to pressure relief devices on vessels, and to flare stacks at the other end. Gases or liquids are released to the flare system and the liquids are knocked out, with the gases combusted at the flare tips. A flare gas recovery compressor recovers most, but not all of the gases. Gas leaving the refinery flare tips is typically composed of a mixture containing hydrogen, methane, ethane, propane and butane. As energy usage is a major cost for a refinery, every effort is made to recover products and avoid flaring. During winter months, a pilot light is used to ensure that flares remain lit - the propane for this pilot light does not come from the refinery stream but is supplied by Speedy Propane.

Flaring is generally an infrequent event which is typically necessary only when there is a loss of cooling water, air, power or steam, or other process upsets, and is the means by which hydrocarbon vapours are safely relieved prior to unit shutdown (AGRA, 1998).

Relatively little is known about the specific emissions that are released to the atmosphere due to flaring activities. This is largely because the ability of a flare to effectively burn waste hydrocarbons is complex, and methods for detailed measurement of flare emissions have been limited (Strosher, 1996). Flare combustion efficiency is specific to each individual flaring operation and is influenced by a number of factors including flare design, operating conditions (including the sequential arrangement of pre-combustion, combustion and post-flame processes), presence of cross winds, mixing of fuel and oxygen, local atmospheric conditions, and composition of waste stream gases (Strosher, 1996, Edwards, 1974). Gas streams with low heating values are unable to maintain a steady flame, resulting in reduced combustion efficiencies and production of undesirable products of incomplete combustion (McCrillis, 1988). Also, strong cross-winds can reduce the combustion efficiency of a flare by tearing away some of the eddies from the flame that contain partially combusted gases (Grouset and Plion, 1987; Gallant *et al.*, 1984).

A number of different flare designs exist for refinery operations that vary in their complexity. Although the design and operation of some flare systems may be simple, the combustion process itself is highly complex. Even under ideal conditions, it can be difficult to achieve the optimum proportions of fuel and oxygen for some flare systems. Thus, flaring tends to lead to products of incomplete combustion.

A recent investigation was conducted to characterize the emissions of flares at two oilfield battery sites in Alberta (*i.e.*, Strosher, 1996). This study concluded that even relatively simple fuel streams (*e.g.*, methane, propane) can produce large quantities of pyrolytic products, although the amounts that escape the flame are relatively small. More complex fuel streams (*e.g.*, longer chain hydrocarbons and mixtures of hydrocarbons) burn with less efficiency than simple fuel streams and higher amounts of pyrolytic products, as well as unburned fuel, can be found in their emissions. The addition of liquid fuels to flare-directed streams impairs combustion efficiency further. Air dispersion modelling was also carried out following the emissions characterization investigations. Among the key results of the theoretical air dispersion modelling (Leahey, 1996) were:

- maximum ground level air concentrations (GLACs) of products of incomplete combustion (PICs) would be localized and expected to occur within several hundred metres of the flare stack; the deposition of materials close to the flare occurs because of the relatively low flow velocities, and consequent plume buoyance, of flares.
- concentrations of PICs decrease rapidly with distance from the maximum GLAC
- maximum predicted GLACs for VOCs are lower than available ambient air criteria
- maximum predicted GLACs for PAHs are comparable to those measured in large industrial cities

Based on the information provided and given that IOL has indicated that the new units associated with the refinery upgrade will not increase the amount of flaring at the IOL Refinery, it can be assumed that the community would not experience adverse health effects as a result of flaring of the upgraded units. Current or future releases from IOL due to flaring would be captured in the ambient air monitoring programs related to VOCs.

5.7.8 Potential Effects on Surface Water and Well Water Quality

Well Water Quality

Concern was expressed regarding whether drinking water wells could be impacted by air emissions from the IOL Refinery. Although the majority of Saint John residents are on municipal water, there are a few residents that obtain their drinking water from private wells. Any contaminants which are able to reach this groundwater in sufficient quantities could result in a potential health risk.

Emissions from the IOL Refinery would not be expected to have a significant impact on the drinking water quality of private wells. As determined in the Problem Formulation section, both PAHs and VOCs were identified as chemicals of potential concern but neither would be expected to migrate into the groundwater at a rate that would be sufficient to pose a health risk. PAHs tend to bind to soils and are thus relatively immobile. Leaching of PAHs through soils into ground water is therefore limited, and elevated well water concentrations would only occur in situations where soil concentrations are seriously elevated. The predicted concentrations of PAHs in the surface soil, both under existing conditions and in the future, were very low; thus they do not represent a health concern. In addition, PAHs are found naturally in the environment and are readily degraded by soil microorganisms. This microbial breakdown of PAHs acts to counter chemical deposition onto the soil thereby limiting the accumulation of PAHs in surface soils.

Similar arguments can be made for VOCs. Due to their volatile nature, VOCs would not be expected to accumulate in soils but would tend to volatilize and disperse into the atmosphere. In addition, VOCs are rapidly degraded by soil microorganisms. Therefore, the potential accumulation of these chemicals in the surface soil would be minimal, as would the likelihood of sufficient amounts of VOCs leaching to groundwater and posing potential health risks to residents who obtain their drinking water from private wells. Furthermore, VOCs are not predicted to increase significantly as a result of the upgrade.

Other refinery air emissions, such as combustion gases and particulates, as well as secondary reaction products (acid aerosols and ozone), would also not be expected to pose potential health risks to residents who obtain their drinking water from private wells. These chemicals will not accumulate in soils to any appreciable extent; therefore, their potential to accumulate in private well water is minimal. If there is continued concern from the public related to potential contamination of drinking water wells, the above qualitative evaluation could be validated by the analysis of an appropriate number of water samples from local wells. However, it should be noted that any evaluation of chemical concentrations in wells will not indicate the source(s) of these chemicals.

Surface Water Quality

Concerns were expressed regarding the potential for emissions associated with the IOL Refinery to impact local surface water quality. One such concern was that sulfur oxides released from the refinery would lead to increased acidification effects. As sulfur oxide emissions are predicted to decrease slightly when the upgraded units are operating (see Section 6.3.1), increased acidification of surface water bodies within the Saint John air shed would not be expected to increase, relative to the current pH status of local surface waters.

Changes in other emissions associated with the upgrade are also unlikely to have any significant impact on surface water quality. PAHs and VOCs are readily degraded and thus do not tend to accumulate in surface waters to an appreciable extent. In addition, VOC are not predicted to increase significantly as a result of the upgrade. Similarly, other refinery air emissions (*i.e.*, combustion gases, particulates, secondary reaction products (acid aerosols and ozone)), would also not be expected to build up in local surface waters. In support of this, a sampling of local water bodies following a particulate deposition event in 1993, and a fire in the hydrocracker at the IOL Refinery (June, 1998), revealed negligible impacts on surface water quality (Pilgrim and Ecobichon, 1993; NB DOE, 1998). Given the nature of the IOL emissions related to the upgrade, which are considerably less than the emissions associated with these two events, it is unlikely that the upgrade would adversely impact surface water quality in Saint John.

If there is continued concern from the public related to potential impacts on surface water quality, the above qualitative evaluation could be validated by the analysis of an appropriate number of samples from nearby water bodies. However, it should be noted that the evaluation of chemical concentrations in surface water will not indicate the source(s) of these chemicals.

5.8 Conservative Assumptions in the Assessment

Within the risk assessment component of the PHRA conducted for the IOL Refinery Upgrade, a number of conservative assumptions were made, both with regard to parameter selected and with the choice of scenarios. These assumptions had to be made in order to ensure that potential risks were not underestimated and would be applicable to all people within the community, and to provide estimates to fill data gaps that were identified and could not be filled within the time limits of the project. It is important to understand the assumed receptor parameters in order to interpret the results of the PHRA. Based on the receptor assumptions adopted, PHRA risk estimates would likely be greater than those that would be experienced by anyone in the community, because upper bound values were assumed for the 95th percentile values for all parameters, and, from a practical point of view, no one individual could have such extreme values for all parameters. The major assumptions used in the PHRA included the following:

- Human receptors were assumed to reside within the vicinity of the IOL Refinery 24 hours/day, 7 days/week for 365 days/year (*i.e.*, residents were assumed never to leave the area, not even to go to work or to do errands, such as grocery shopping, vacations, *etc.*).

- It was assumed that the human receptor was also acutely sensitive to all effects of all the chemicals of potential concern. Thus, the exposure limits used in the risk assessment were based on the most sensitive toxic endpoint in the most sensitive individuals. Additional"safety" factors have been applied to exposure limits by the responsible agencies. Therefore, ER values would have to be substantially greater than 1.0 before any actual adverse health effects could be observed.

- Receptors were conservatively assumed to be exposed to emissions from the IOL Refinery Upgrade for 70 years (see Appendix E).

- Risk estimates presented in the PHRA were calculated for the maximum point of ground level impingement of the emissions. Any movement away from the maximum point of impingement would result in lesser ground level air concentration of the emissions. Clearly, no one individual would be at this location all of the time.

- The IOL Refinery was assumed to operate an additional 30 years with the environmental control technologies equivalent to either the existing (existing study area scenario) or future (future study area scenario) controls.

- Indoor air concentrations of substances were not assumed to be zero, but were conservatively considered to be 75% of those predicted for outdoor air.

- It was assumed that 30% of the total produce (including vegetables, fruits, berries, jams, *etc.*) consumed by residents on a yearly basis was locally grown in soils and exposed to air concentrations at the maximum point of impingement of air emissions from the facility.

- Air dispersion modelling results used in the risk assessment tended to overestimate the contributions of sources considered in the existing and future study area scenarios to the existing ground level ambient chemical concentrations in the air. This is the result of a number of conservative assumptions incorporated in the model parameters, and the combination of a series of unique meteorological conditions with upper bound emission rates to calculate the maximum point of impingement. The likelihood of these unique conditions occurring simultaneously is remote. Nonetheless, they form the basis of the exposure estimates in the human health risk assessment. This also results in a very conservative estimate of the risk.

- The magnitude of the change between the existing study area and future study area scenarios is expected to be exaggerated as a result of the derivation of the emission rates.
- For particulate modelling by Stantec (1999a), all particulate sources modelled were conservatively assumed to have properties the same as PM_{10}.

5.9 Limitations and Uncertainties in the Assessment

As in any health risk assessment which evaluates potential future health impacts, the findings of the assessment depend on the availability of site specific data (such as air concentrations, soil concentrations from the specific study area) and on information in the scientific literature related to the toxicology and behaviour of the selected substances in the environment. As discussed in the previous section, a number of assumptions have been made related to receptor behaviours in order to both compensate for data gaps and to simplify complex systems thus making it more manageable from a modelling perspective. Every effort has been made to ensure that the data used in this assessment adequately represent conditions at the site, and that any assumptions that were made do not compromise the efforts to provide a conservative assessment of the potential risks to the public as a result of the IOL Refinery. However, a number of limitations exist as a result of the available data and assumptions which ultimately contribute to some level of uncertainty in the results of the assessment. In all cases, the approach to the current assessment was to ensure that the assumptions err on the cautious or conservative side so as not to underestimate potential health risks. In many cases, validation steps are recommended (Section 9.0) to validate key assumptions or provide additional data to reduce this inherent uncertainty. The key limitations of the current assessment are listed below.

- No site specific data were available for the IOL Refinery on actual or predicted future stack or fugitive emissions for either PAHs or VOCs. As a result, the potential future emissions of these substances were estimated.
- Specific assumptions, critical to the modelling were made based on the understanding of the key issues. As a result, the assessment would be subject to changes should the underlying data or assumptions change (*e.g.*, stack emission rates differ significantly from those utilized by Stantec (1999a,b), the refinery operates for more than 30 years without modification or upgrading).
- Modelling data were not available for the IOL Refinery Upgrade in isolation of other industrial sources (*e.g.*, CB, IP, LS, IPP). This means it has been assumed that the stack emissions from the IOL Refinery alone would disperse separately in the same manner as the combined emissions from IOL, CB, IP, LS and IPP.
- Stantec (1999a,b) air dispersion modelling used meteorological data for 13 months only (1997-1998).

- For future scenarios, Stantec's (1999a,b) predictions assumed that all other sources of chemicals remained constant (*e.g.*, no increase in vehicular traffic; no increases in emissions from other facilities, *etc.*).

- Air quality data for sites within New Brunswick or even the Maritimes were limited and a considerable amount of data used to define "background"air and soil quality were obtained from studies conducted in Ontario, Quebec and in some cases the USA. These studies were often associated with urban areas and thus they may not represent ideal surrogates for "background" sites. A number of key assumptions, including the proportion of total PAHs adsorbed to particulate matter, were estimated from the literature. Similarly, ambient monitoring data were used to characterize the PAH profile from the refinery. These data would be reflective of all sources of PAH within the Saint John area (not just those associated with the refinery). The relevance of these data has not been substantiated although there is good reason to believe that this approach over-estimated potential risks from the IOL Refinery Upgrade.

- Although a significant amount of data were available which characterized VOC levels in Saint John, NB, it was never established which specific VOCs would be expected to originate through fugitive and stack emissions from the IOL Refinery, the emission rates of these VOCs, or the potential change in the species profile as a result of the IOL Refinery Upgrade. It was reasonable to expect that the total quantity of fugitive VOC emissions would not be elevated but the proportions of the specific VOCs may change, reflecting the shift in production from heavy to lighter fuels. This issue could be neither qualified or quantified for the PHRA.

5.10 Summary of Results of the Risk Assessment

- ***Polycyclic Aromatic Hydrocarbons***: PAHs in existing ambient air in Saint John in areas surrounding the refinery would not be expected to result in measurable adverse health outcomes in the community. The IOL Refinery Upgrade would be expected to increase PAH levels slightly, however this increase would not be expected to result in measurable effects on public health.

- ***Volatile Organic Compounds***: VOCs are slightly elevated in the existing ambient air within areas surrounding the refinery compared to health-based exposure limits. These values however, are typical of an urban environment in general and indicate the reason that regulatory agencies have focussed on VOC abatement programs. The IOL Refinery Upgrade is not expected to increase VOC compared to existing operations and therefore would not be expected to impact ground level ambient air concentrations.

- ***Combustion Gases***: Sulphur dioxide is generally similar to other urban background areas and below guidelines in Saint John in areas surrounding the IOL Refinery. Some exceedances of guideline values have been observed at the Forest Products monitoring station. Less frequent exceedances were reported for Champlain Heights, Forest Hills and other community monitoring stations. It is possible that sensitive members of the community (*i.e.*, those with asthma or other respiratory conditions) would experience acute or short-term respiratory responses (*e.g.*, coughing, irritation, short-term decreased lung function) if they were at the locations when these exceedances occurred. However, such responses, although undesirable, would likely be of short duration and at infrequent intervals, and would not be expected to results in chronic health outcomes.

Sulphur dioxide emissions from the refinery are expected to decrease as a result of the refinery upgrade. However, the predicted ground level air concentrations of sulphur dioxide are only expected to decrease slightly. This observation indicated that the IOL Refinery is a smaller contributor to the ground level air concentrations of sulphur dioxide than the combination of other industrial and non-industrial sources.

Ambient concentration of the other combustion gases evaluated (*i.e.*, nitrogen oxides, carbon monoxide), are projected to increase as a result of the IOL Refinery Upgrade. Projected future concentrations of these chemicals as a result of the IOL Refinery Upgrade, would not be expected to result in measurable adverse health outcomes in the community, since they are less than air quality guidelines.

- ***Particulate Matter***: Particulate matter are predicted to increase as a result of the IOL Refinery Upgrade. This increase is projected to result in marginal exceedances of conservative air quality criteria for various sizes of particulate matter, but not the proposed Canada Wide Standard for these substances. Since many of these increases would result in concentrations that are within the range of reported values already, measurable adverse health outcomes in the community as a result of the IOL Refinery Upgrade would not be expected.

- ***Secondary Reaction Products***: Ambient ozone levels within Saint John in areas in the vicinity of the IOL Refinery were below the 1-hour National Objective in 1996 and 1997. However, the annual National Objective for ground level ozone was exceeded. Other areas in New Brunswick have been reported to exceed the annual objective, and this is thought to be primarily due to transboundary pollution. The IOL Refinery Upgrade is not expected to have any noticeable impact on the ozone levels in Saint John.

  Existing ambient concentrations of acid aerosols within the Saint John area (as estimated from sulphur dioxide and particulate data), indicate that a portion of the population most susceptible to the irritating effects of acid aerosols might be negatively impacted (on a short-term basis) during times when the estimated concentrations exceed the health-based guideline derived by the Study Team. However, since the future study area scenario indicated that ground level concentrations of SO_2 and particulate matter in the community will not change substantially, and/or remain within air quality guidelines, the IOL Refinery Upgrade was not predicted to affect these parameters. Therefore, the IOL Refinery Upgrade would not be expected to result in measurable adverse health outcomes in the community from acidic aerosols.

- ***Other Specific Community Concerns***: The community indicated several issues which were of concern during public consultation including: noise, odour, light, new technologies, and upset and accident conditions. Based on the available data and professional judgement, these issues do not appear to pose a significant concern with respect to public health. However, if continued concern is expressed by the community relating to these issues, assumptions made in this assessment could be validated with further analyses. Recommendations related to these issues are presented in Section 9.0.

6.0 PUBLIC HEALTH ASSESSMENT RESULTS AND DISCUSSION

The public health assessment component of the PHRA was aimed at defining the public health benefits or impacts to be accrued to the community by specific engineering changes at the facility. The PHRA focussed on the identification of the current health status, issues and concerns in the community, community outreach, and identification of available data sources. These were accessed in order to evaluate the public health status of the Saint John community at the present time. This "snapshot" of the community's health was then extrapolated and integrated with the health risk assessment in order to evaluate the potential impact of the IOL Refinery Upgrade.

6.1 Identification of Risks and Public Health Concerns

6.1.1 Review of the Literature of Regional Interest

Potential public health issues and concerns were identified using previous health studies of the Saint John community, notes from meetings with key stakeholder and community groups, a public open-house drop-in session and the published scientific literature. Table 6-1 summarizes the information obtained through this process.

The public stakeholder meetings and the drop-in session provided valuable information about the health issues of concern in the community, so that these could be specifically included in the public health assessment. The published scientific literature outlining study results for the Saint John area (as well as a selected few other studies) highlighted specific health concerns related to various air quality issues relevant to Saint John, including: airborne particulate matter, ozone, and SO_2. These studies examined the public health concerns related to these air quality issues, including affect on respiratory and cardiac hospital admissions, decreased lung function, and increased emergency room care for respiratory diseases.

There are a great many reports of associations of morbidity and/or mortality of specific populations as a result of exposure to ambient levels of air pollutants. A comprehensive review of all of this literature was beyond the scope of the current assessment, and considered of limited relevance since virtually all urban air and human health epidemiology studies are retrospective in nature, and the current PHRA is prospective in nature. While many of the studies of urban populations might demonstrate generalized responses to air pollutants, the main question of this health assessment was whether there would be a net increase in specific pollutants to the existing exposure values over ambient conditions, as a result of the IOL Refinery Upgrade. The vast majority of the epidemiology literature does not provide an assessment of specific pollutants in isolation from others and therefore is difficult to use directly to answer the health question that the PHRA is addressing.

Table 6-1 Review of Literature

Authors	Year	Population	Purpose	Results
Burnett RT, et al	1999	Hospital admissions for respiratory, cardiac, cerebral vascular, and peripheral vascular in Toronto from 1980-1994	Study effects of particulate and gaseous air pollution on cardiorespiratory hospitalizations	Air pollution was weakly associated with hospitalization for cerebral and peripheral vascular; Increases in PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$ increased respiratory and cardiac hospital admissions
Burnett RT, et al	1998	Number of daily deaths for non-accidental causes in 11 Canadian cities from 1980 to 1991	To determine the risk of premature mortality due to the urban ambient air pollution mix in 11 Canadian cities	NO_2 had 4.1% increased risk on mortality, ozone at 1.8%, SO_2 at 1.4%, and CO at 0.9%; ambient air pollution from the burning of fossil fuels is a risk factor for premature mortality
Burnett RT, et al	1997	Daily number of hospitalizations over a 3,927-day period from 1981 to 1991 in Canada's 10 largest cities	To explore the association between ambient carbon monoxide levels and hospitalizations for congestive heart failure in the elderly in 10 Canadian cities	Ambient air pollutants were positively associated with daily fluctuations in hospital admissions for congestive heart failure in the elderly; specific air pollutants include CO, NO_2, $SO_{.1}$, and a coefficient of haze
Stedman JR, et al	1997	Great Britain in the summers of 1993 and 1995	Study emergency hospital admissions for respiratory disorders attributable to summer time ozone episodes	0.1% and 0.35% of hospital admissions for 1993 and 1995 for respiratory disorders can be attributed to levels of ozone above 50 ppb; this estimate is sensitive to threshold assumptions
Burnett RT, et al	1997	12.6 million people in 16 Canadian cities	Study association between ozone and hospitalization for respiratory disease	The daily high hour concentration of ozone recorded 1 day previous to admission was positively associated with respiratory admissions in April to December, but not the winter months; particulate matter and CO were positively associated with respiratory hospitalizations

Table 6-1 Review of Literature

Authors	Year	Population	Purpose	Results
ARMA	1997	review	Study air quality and public health in Saint John	Saint John has elevated ground-level ozone and high levels of acidic particles; ozone is associated with increases in emergency room visits for asthma and hospital admissions for lung conditions; long-term exposure to acidic particles adversely effects lung growth; public health effects appear to be important in qol and economic impact
Spengler JD, et al	1996	24 North American cities (6 specific to Canada); Saint John was not included (no cities specific to New Brunswick were used)	Study the results air pollution monitoring of particle strong acidity over a 1 year period	Eastern United States and Southern Canada experienced greatest particle strong acidity; Low particle strong acidity in western and Midwestern United States and Canada
Raizenne M, et al	1996	10,251 children (8-12) in 24 North American cities (6 specific to Canada)	Study the public health effects of particle strong acidity over a 1 year period	Particle strong acidity is associated with statistically significant decreases in FVC and $FEV_{1.0}$ suggesting deleterious effect on lung growth, development, and function
Brook JR, et al	1996	Saint John air in 1994	Report the results of the 1994 air monitoring activities	Cite preliminary conclusions regarding measurements of H^+, SO_4, PM_{10}, and $PM_{2.5}$;
Morris RD, et al	1995	Hospital admissions data in 7 US cities from 1986 through 1989	To explore the association between hospital admissions for congestive heart failure and air pollution	Ambient CO levels were positively associated with hospital admissions for congestive heart failure
Delfino RJ, et al	1993	1,279 discharge records from 14 Montreal hospitals compared with health insurance database in Quebec	Study the use of hospital databases for research into the respiratory effects of air pollution	Agreement levels were 94.9% for asthma, 75.5% for all other respiratory diseases, 93.1% for nonrespiratory comparison group

Table 6-1 Review of Literature

Authors	Year	Population	Purpose	Results
Bell J	1984	80,521 residents of Saint John	Study the effect of sulphur dioxide on outpatient department visits due to breathing difficulty in 1983	Comparing March (low SO_2) with July (high SO_2) there appears to be no connection between number of outpatient visits due to breathing difficulty

6.1.2 Current Public Health Status of Saint John Community

The assessment of the current public health status in the community focussed on gathering information that would be important in evaluating the causal factors of the health concerns and issues identified above in Section 6.1.1.

Demographic Profile of the Saint John Community

Table 6-2 represents the statistical profile of the Saint John Metropolitan Census Area and comparison of this information with the province of New Brunswick. Overall, persons residing in the Saint John community are slightly younger than those in the rest of the province. They also reached a higher education level, had a higher average total income level, and a lower unemployment rate than the rest of the province.

Table 6-2. Statistical Profile of Saint John Metropolitan Area, New Brunswick: 1996

Characteristics	Saint John	New Brunswick
Population in 1996	125705	738133
Average age of the population	35.8	36.1
Highest level of schooling for the population age 25 yrs and over (%)		
Less than grade nine	12.2	19.4
High school certificate or higher	67.4	60.6
Trades or non-university certificate or higher	43.3	39.3
Completed university	14.2	13.1
Labour force of population age 15 yrs and over		
Average total income	$23,012	$20,755
1996 unemployment rate	13.1	15.5

Table 6-2. Statistical Profile of Saint John Metropolitan Area, New Brunswick: 1996

Characteristics	Saint John	New Brunswick
Selected family characteristics		
Average number of persons in married or common-law families	3.2	3.1
Average total income of married or common-law families	$54,186	$48,527
Average number of persons in lone-parent families	2.5	2.5
Average total income of lone-parent families	$24,244	$23,762

[1]Data provided by Statistics Canada.

Asthma Prevalence

Saint John (New Brunswick Lung Association)

- Slightly more than 1/3 (36%) of all households in the Greater Saint John area report that at least one household member had some form of respiratory illness such as asthma (25%) or lung disease (7%).
- Among those households, the incidence of asthma was highest (70%), followed by heart disease (33%) and lung disease (20%).

Table 6-3 presents asthma prevalence for the province of New Brunswick and Canada. New Brunswick showed an overall lower prevalence of asthma than the rest of Canada.

Table 6-3 Asthma Prevalence for New Brunswick and Canada

	Number	Percentage (%)
Canada	2245200	7.8
New Brunswick	48200	6.6

Source: Statistics Canada. National Population Health Survey, 1996-97.

Smoking Prevalence

- In a 1990-1991 survey of over 1000 randomly selected Saint John residents aged 15 and over, 29% of the sample reported that they currently smoked cigarettes daily.
- This compared with 25% for the province of New Brunswick as a whole, and 26% for all of Canada.

- The New Brunswick Lung Association 1995 Youth Smoking Survey of 2,624 Saint John high school students aged 15-19 found that 63% of respondents reported that there was at least one regular smoker at home.

Hospital Utilization

Figures 1 through 4 represent data on hospital utilization taken from the report "Health Status of New Brunswickers, Third Report 1989-1993", produced by Health and Community Services of New Brunswick. This report is a comprehensive look at the overall health of those persons residing in New Brunswick. For each diagnoses the average rate of both Hospital Care Days and Separations were calculated for the years 1988 through 1993.

The province is divided into 7 regions (see map in Appendix H). For this report we focus on a comparison of regions II and III. Region II encompasses Saint John City and region III encompasses Fredericton. Rates for the entire province of New Brunswick are also shown. Both Hospital Care days and Separations are examined. Hospital Care Days are the number of days an individual spent being cared for in the hospital. This is sometimes referred to as "length of stay." Hospital separations encompass all of the events of people leaving the hospital and includes both those who left the hospital alive and dead. In contrast "discharges" include only those patients leaving the hospital alive.

The diseases are classified according to their ICD-9 codes and are presented separately for males and females. (PMIC, 1991) The codes used were: disease of the endocrine system (240-246, 250-259), diseases of the blood (280-289), diseases of the circulatory system (390-459), ischaemic heart disease (IHD) (410-414), cerebrovascular disease (CVD) (430-438), diseases of the respiratory system (460-519), COPD and allied conditions (490-496), diseases of the digestive system (520-579), diseases of the skin (680-709), and mental disorders (290-319).

Figure 1. Hospital Utilization for Selected Diagnoses for Males According to Hospital Care Days 1988-1993

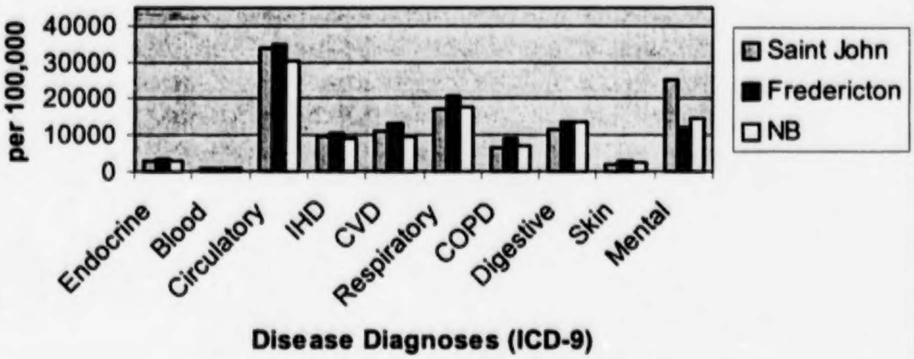


Figure 1 compares the average number of Hospital Care Days for each diagnosis per 100,000 population for males from the Saint John (Region II) area versus males from Fredericton (Region III), and the province of NB for the years 1988 to 1993. The overall rates were similar for all of the diagnoses except for the diagnosis of mental disorders. It is important to note that no differences were observed in the average number of hospital care days between any of the groups for either all causes of respiratory disease (Respiratory) or Chronic Obstructive Pulmonary Disease (COPD). However, there was a difference in the average number of hospital care days between the regions for the diagnosis of mental disorders; with Saint John having 25,040 average hospital care days and Fredericton having 12,290. The rates for the province of NB were similar to that of Fredericton. The reasons for this may have to do with differences in access to care, available services, and referral patterns for mental health conditions between the two regions.

Figure 2. Hospital Utilization for Selected Diagnoses for Females According to Hospital Care Days 1988-1993

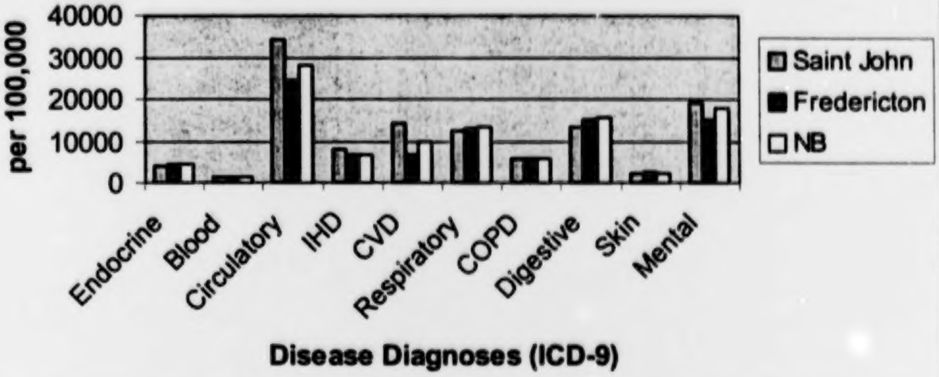


Figure 2 compares the average number of Hospital Care Days for each diagnosis per 100,000 population for females from Saint John, Fredericton and the province of NB for 1988 to 1993. There were no large differences observed in the average number of hospital care days between any of the groups for either respiratory disease (Respiratory) or Chronic Obstructive Pulmonary Disease (COPD). However, there was still a slight difference in the average number of hospital care days for the diagnosis of mental disorders. It was also noted that females in Saint John had a higher rate of hospital care days for cerebrovascular disease (CVD) and all cause diseases of the circulatory system (Circulatory) than either Fredericton or the province of NB.

Figure 3. Hospital Utilization for Selected Diagnoses for Males. According to Separations, 1988-1993

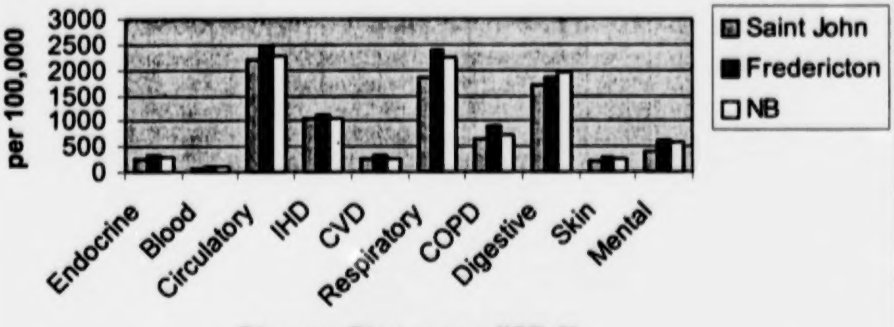
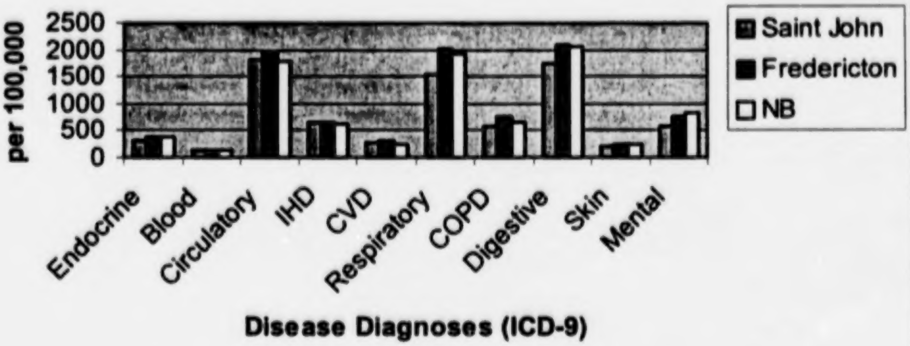


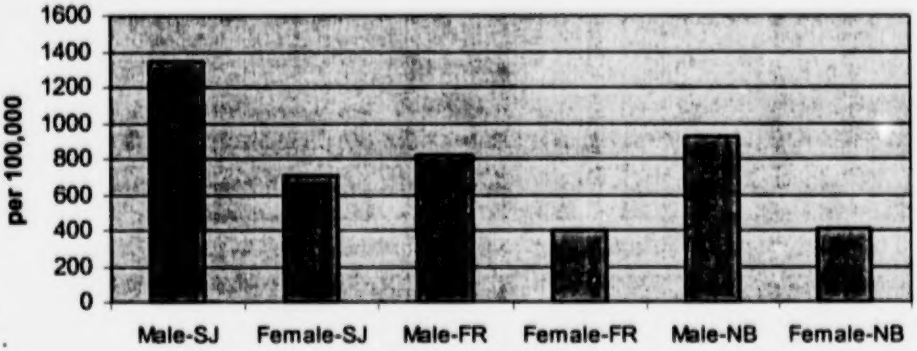
Figure 4. Hospital Utilization for Selected Diagnoses for Females. According to Separations, 1988-1993



Figures 3 and 4 compare the average number of Separations for each diagnosis per 100,000 population for males and females from the same two regions and the province of NB. For both males and females the overall rates were similar for all of the diagnoses. Overall, the average separation rates across all disease categories were higher in Fredericton (Region III) and the province of NB.

Figures 5 through 10 compare lung cancer incidence and mortality rates between the locations of Saint John and Fredericton over a 10 year period from 1988-1997. This information was obtained from Health and Community Service's Provincial Epidemiology Service (1999). Each rate was calculated using the 1992 population for each location. While in this section only information on lung cancer is presented, both incidence and mortality rates for the leading 25 cancer diagnoses for each location are presented in Appendices J and K.

Figure 5. Lung Cancer Incidence Rates by Sex and Location, 1988-1997



Cancer Incidence and Mortality

Figure 5 compares lung cancer incidence rates by sex between Saint John (SJ), Fredericton (FR) and the province of New Brunswick (NB) per 100,000 population. The highest incidence rate observed was for males in Saint John (1,340 cases/100,000), followed by males in New Brunswick (920) and Fredericton (820). This same pattern was observed for females, with the highest rate for females in Saint John (710) followed by New Brunswick (410) and Fredericton (400) respectively.

Figure 6. Total Lung Cancer Incidence Rates by Location, 1988-1997

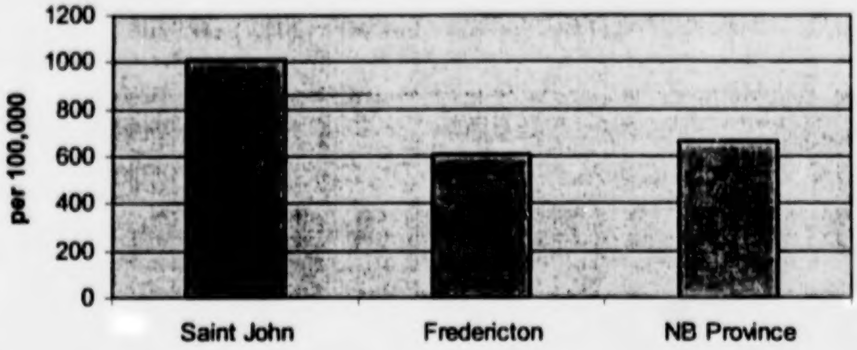
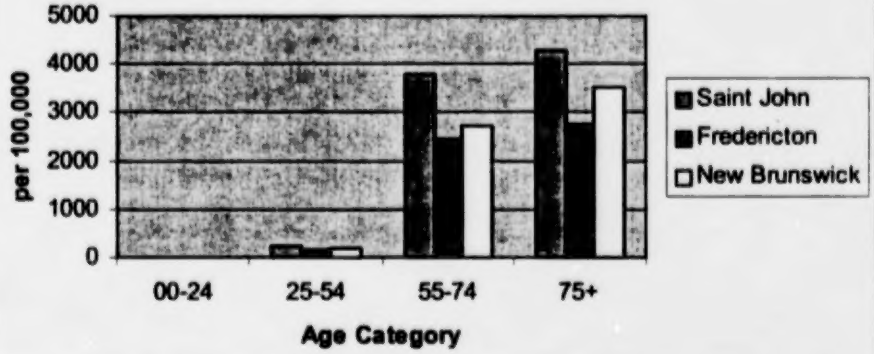


Figure 6 presents the total lung cancer incidence rates per 100,000 for all three locations. The totals are presented separately for ease of interpretation. Again, Saint John has the highest incidence rate (1010), followed by the province of NB (661) and Fredericton (604).

Figure 7. Age-specific Lung Cancer Incidence Rates by Location, 1988-1997



Age-specific cancer incidence and mortality rates are presented here as opposed to age-adjusted rates. Adjusted rates provide a summary value that removes the effect of differences in a population (in this case age) structure to allow for valid comparisons between groups or over time. However, its actual value is meaningless since it has been statistically constructed based on the choice of a standard. Age-specific rates are unconfounded and provide the most detailed information about the pattern of the disease in a population. The age-specific rates for all cancers examined (incidence and mortality) are presented in the appendices.

Figure 7 presents the age-specific lung cancer incidence rates per 100,00 population. In this case the incidence rates are low to non-existent for all locations in the younger age groups with most cases of lung cancer emerging in the older age groups. A similar pattern is seen in each location in the older age groups where Saint John has the highest rate followed by New Brunswick and Fredericton.

Figures 8 through 10 examine the mortality rate per 100,000 population for each of the three locations. While mortality rates are generally lower across each location the pattern remains the same as with cancer incidence which is to be expected. It is interesting to note that in the older age groups, incidence and mortality are very similar. This indicates that when lung cancer is diagnosed at a later age, there is an overall lower rate of survival.

Figure 8. Lung Cancer Mortality Rates by Sex and Location, 1988-1997

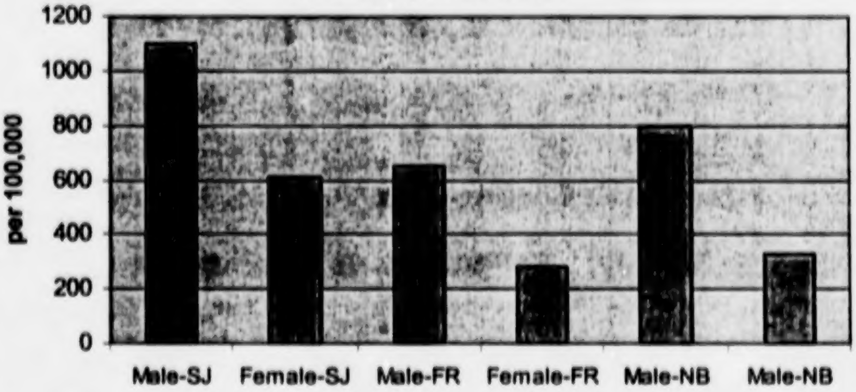


Figure 9. Total Lung Cancer Mortality Rates by Location, 1988-1997

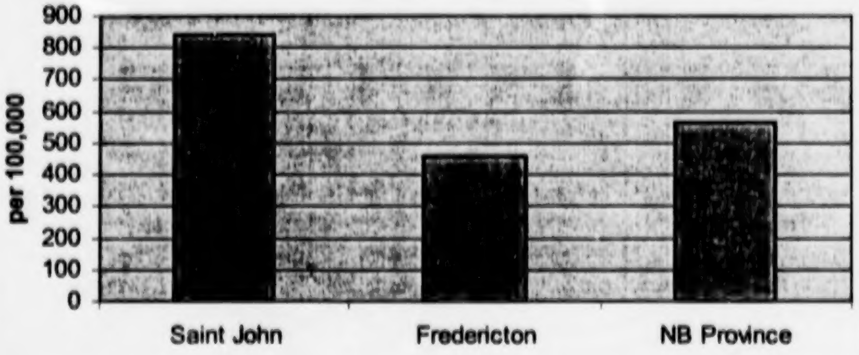
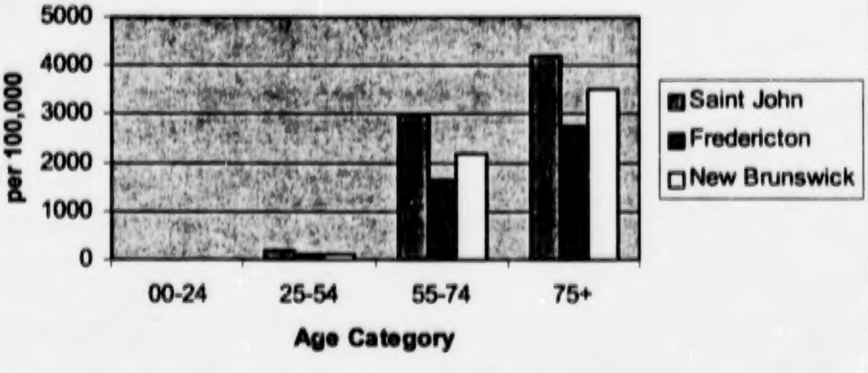


Figure 10. Age-specific Lung Cancer Mortality Rates by Location, 1988-1997



6.2 Predicted Change in Public health Impact

6.2.1 Cancer Outcomes

To determine which endpoints to investigate as potentially being affected by the upgrade, the incidence rates of cancers in Saint John as well as the potential of the chemicals emitted by the refinery to cause such cancers were examined. Due to the higher incidence of lung cancer and stomach cancer in Saint John as compared to Fredericton, it is important to look at possible carcinogens in the Saint John region, and comparisons of these sources with the emissions of the industries in the existing and future study areas, including the IOL Refinery, to enable evaluation of any potential impact of the upgrade on this health outcome. Through the scientific literature available, it was determined that stomach and lung cancer are two possible endpoints that could be affected by the chemicals, specifically PAHs, emitted from various sources around the city. To accomplish a comparison, a published methodology based on epidemiological principles was utilized (Carlo *et al*, 1988). This methodology accounts for multiple risk factors and the percent contribution of the various risk factors to public health outcome being assessed.

The health risk assessment modelling (see Section 5) evaluated PAHs, specifically the benzo[a]pyrene group, using the whole mixture model for PAHs (identified as B[A]Ps), and compared modelled health risk estimates between the background, existing ambient, existing study area and future study area scenarios. Thus, the first step of the process was to calculate the incremental change that would be expected in lung and stomach cancers using the results from the health risk assessment data for the Existing Study Area Scenario and the Future Study Area Scenario:

Incremental Change = Future Study Area Scenario - Existing Study Area Scenario

The values for the 50th percentile from the risk assessment modelling (See Appendix J) were used in these calculations because they were felt to best represent the population, and would be most comparable to the public health evaluation data. The epidemiology data represented the average of the population, thus it is most appropriate to compare it with the average, or 50th percentile, from the risk assessment modelling. Only inhalation and oral exposure were examined which coincides with lung and stomach cancers. The results of these calculations are shown in Table 6-4.

Table 6-4 Incremental Change in the Benzo[a]pyrene Group Due to IOL Refinery Upgrade

Chemical [1]	Silver Falls	Forest Hills	Champlain Heights
B[A]P Inhalation	4.00×10^{-8}	1.32×10^{-8}	0.26×10^{-7}
B[A]P Oral	0.53×10^{-10}	1.72×10^{-11}	0.34×10^{-10}
B[A]Ps Inhalation	1.53×10^{-7}	0.51×10^{-7}	1.01×10^{-7}
B[A]Ps Oral	2.04×10^{-10}	0.69×10^{-10}	0.34×10^{-10}

[1] B[a]P represented the benzo[a]pyrene group evaluated in the risk assessment using the individual PAH model and B[a]Ps represents the benzo[a]pyrene group evaluated using the whole mixture model for PAHs.

Once the incremental change was calculated, the risk factors of lung cancer were obtained from the published scientific literature to determine the attributable risk of various exposures. Attributable risk is a tool that estimates the amount of disease that will be eliminated or prevented if a particular exposure is eliminated. From the scientific literature, the major cause of lung cancer was found to be personal uses of tobacco. Data show that tobacco accounts for 90 percent of male lung cancer and 79 percent of female lung cancer, therefore the residual attributable risk is 10 percent and 21 percent respectively. The residual attributable risk is the maximum proportion of the disease that can not be explained by tobacco (Table 6-5). If smoking decreases in a community, the attributable risk of tobacco would also decrease; however, smoking trends would have to be followed closely to detect this potential change.

Table 6-5. Attributable Risk for Lung Cancer

Risk Factors	Attributable Risk—Males	Attributable Risk—Females
Tobacco	90% (Schottenfeld et al, 1996)	79% (Schottenfeld et al, 1996)
Residual Risk	10%	21%

To calculate the residual rate, the residual attributable risk is multiplied by the incidence of the disease in the population or the mortality of the disease:

Residual Rate = Residual Attributable Risk x Incidence of the Disease per 100,000
or
Residual Rate = Residual Attributable Risk x Mortality of the Disease per 100,000

As shown in the cancer appendix, the incidence of lung cancer in males in Saint John is 1340 per 100,000 population. Thus, the residual rate for lung cancer for males is 1.34×10^{-3} (10% of 13.40×10^{-3}). The incidence of lung cancer in females in Saint John is 710 per 100,000. Thus, the residual rate for lung cancer for females is 1.49×10^{-3} (21% of 7.10×10^{-3}).

To calculate the maximum impact that the incremental effect of future study area scenario, and indirectly, the IOL Refinery Upgrade, will have on lung cancer, the residual rate is combined with the incremental change. This analysis assumes that the population risk for Saint John is applicable to the community in the environs of the IOL Refinery.

Maximum Impact = Incremental Change + Residual Rate

Table 6-6 shows the maximum impact that the carcinogenic benzo[a]pyrene group can have on lung cancer incidence in Saint John. The analysis demonstrates that the incremental change (see Table 6-4, inhalation route) would be approximately 10,000-fold less than the total residual risk factors for lung cancer other than using tobacco products. Therefore, no measurable impact on the incidence of lung cancer as a result of the IOL Refinery Upgrade would occur in the Saint John community.

Table 6-6 Maximum Impact of Changes in the Benzo[a]pyrene Group on Lung Cancer Incidence

Chemical [1]	Silver Falls		Forest Hills		Champlain Heights	
B[A]P Inhalation	Current	Future	Current	Future	Current	Future
Males	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}
Females	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}
B[A]Ps Inhalation	Current	Future	Current	Future	Current	Future
Males	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}	1.34×10^{-3}
Females	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}	1.49×10^{-3}

[1] B[a]P represented the benzo[a]pyrene group evaluated in the risk assessment using the individual PAH model and B[a]Ps represents the benzo[a]pyrene group evaluated using the whole mixture model for PAHs.

Table 6-7 shows the maximum impact that the carcinogenic benzo[a]pyrene group can have on lung cancer mortality in Saint John, as compared to lung cancer incidence rates discussed above. The mortality rate for lung cancer is 1100 per 100,000 for males and 610 per 100,000 for females. The residual rate for males is 1.10×10^{-3} and 1.28×10^{-3} for females. Again, the incremental contribution (see Table 6-4, inhalation route) of possible PAHs in emissions in the future study area scenario for lung cancer was 10,000-fold less than the total residual rate. Therefore, no measurable impact on the mortality due to lung cancer in the community would be associated with the IOL Refinery Upgrade. Overall, there would be no measurable public health benefit to the community in terms of lung cancer by upgrading the facility.

Table 6-7 Maximum Impact of Changes in the Benzo[a]pyrene Group on Lung Cancer Mortality

Chemical [1]	Silver Falls		Forest Hills		Champlain Heights	
B[A]P Inhalation	Current	Future	Current	Future	Current	Future
Males	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}
Females	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}
B[A]Ps Inhalation	Current	Future	Current	Future	Current	Future
Males	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}	1.10×10^{-3}
Females	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}	1.28×10^{-3}

[1] B[a]P represented the benzo[a]pyrene group evaluated in the risk assessment using the individual PAH model and B[a]Ps represents the benzo[a]pyrene group evaluated using the whole mixture model for PAHs.

The same calculations were completed for stomach cancer. Table 6-8 shows the risk factors for stomach cancer, and the attributable risk based on scientific literature. The major cause of stomach cancer was found to be diet and nutrition. Literature shows that diet and nutrition is the cause of 20 to 60 percent of all cancers. Since no data gave numbers specific to stomach cancer, an average of this number was used for the attributable risk due to diet and nutrition for stomach cancer. The residual risk for stomach cancer, 47.3 percent, is the maximum proportion of the disease that can not be explained by diet/nutrition, gastroenterostomy, and genetic causes. There are other risk factors including radiation exposure, alcohol consumption, tobacco use, and the presence of *h. pylori* which also would be contained in this residual risk number, since there are no specific risk attribution values for these factors.

Table 6-8 Attributable Risk for Stomach Cancer

Risk Factors	Attributable Risk—Males/Females
Diet/Nutrition	20-60% (average=40%) (Doll et al, 1994)
Gastroenterostomy	8.7% (Schottenfeld et al, 1996)
Genetic	4%
Residual Risk	47.3%

As shown in the cancer appendix, the incidence of stomach cancer in males and females in Saint John is 125 per 100,000. Thus, the residual rate for stomach cancer is 5.9×10^{-4} (47.3% of 125 per 100,000).

To calculate the maximum impact on stomach cancer from the future study area scenario, and thereby indirectly for the IOL Refinery Upgrade, the residual rate was added to the incremental change using the formula described above for lung cancer. Table 6-9 shows the maximum impact that the carcinogenic benzo[a]pyrene group can have on stomach cancer incidence in Saint John following oral exposure. The incremental contribution (see Table 6-4) of possible PAHs in emissions in the future study area scenario to stomach cancer was 10,000,000-fold less than the total residual rate. Therefore, no measurable impact on incidence due to stomach cancer in the community associated with the IOL Refinery Upgrade.

Table 6-9 Maximum Impact of Changes in the Benzo[a]pyrene Group on Stomach Cancer Incidence

Chemical [1]	Silver Falls		Forest Hills		Champlain Heights	
B[A]P Oral	Current	Future	Current	Future	Current	Future
Males/Females	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}
B[A]Ps Oral	Current	Future	Current	Future	Current	Future
Males/Females	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}	5.9×10^{-4}

[1] B[a]P represented the benzo[a]pyrene group evaluated in the risk assessment using the individual PAH model and B[a]Ps represents the benzo[a]pyrene group evaluated using the whole mixture model for PAHs.

Table 6-10 shows the maximum impact that the carcinogenic group benzo[a]pyrene can have on mortality due to stomach cancer in Saint John. The mortality rate for stomach cancer is 80.7 per 100,000 for males and females combined. The incremental contribution (see Table 6-4) of possible PAHs in emissions in the future study area scenario to stomach cancer was 10,000,000-fold less than the total residual rate. Therefore, no measurable impact on the mortality due to stomach cancer in the community would be associated with the IOL Refinery Upgrade. Overall, there would be no measurable public health impact on the community in terms of stomach cancer rates by upgrading the facility.

Table 6-10 Maximum Impact of Changes in the Benzo[a]pyrene Group on Stomach Cancer Mortality

Chemical [1]	Silver Falls		Forest Hills		Champlain Heights	
B[A]P Oral	Current	Future	Current	Future	Current	Future
Males/Females	$3.82_{4} \times 10^{-}$	$3.82_{4} \times 10^{-}$	3.82×10^{-4}	3.82×10^{-4}	3.82×10^{-4}	3.82×10^{-4}
B[A]Ps Oral	Current	Future	Current	Future	Current	Future
Males/Females	$3.82_{4} \times 10^{-}$	$3.82_{4} \times 10^{-}$	3.82×10^{-4}	3.82×10^{-4}	3.82×10^{-4}	3.82×10^{-4}

[1] B[a]P represented the benzo[a]pyrene group evaluated in the risk assessment using the individual PAH model and B[a]Ps represents the benzo[a]pyrene group evaluated using the whole mixture model for PAHs.

6.2.2 Non-Carcinogenic Health Outcomes

The health risk assessment examined the potential impact the IOL Refinery Upgrade would have on possible health outcome other than cancer by comparing data between the existing and future study area scenarios. The emissions potentially associated with non-carcinogenic health outcomes include carbon monoxide, the aldehyde group of chemicals, NO_x, various components of airborne particulate matter (PM_{10}, $PM_{2.5}$, TSP), ozone, and SO_2. These emissions potentially related to non-carcinogenic health outcomes s were evaluated qualitatively in the risk assessment, and will be presented similarly with respect to their potential impacts on public health of the community. A quantitative assessment was conducted because it made maximum use of the data without creating potential ecologically fallacies that could have resulted from a quantitative assessment.

The concentration of carbon monoxide (CO) is expected to increase 37.1% at the stack, as found in the risk assessment, and this increase would result in a somewhat lesser increase in ground level CO concentrations in the community (22 - 24%; Section 5.3.3). The conclusion of the health risk assessment was that the increase in ground level ambient air CO concentrations in the community will not exceed the existing air quality guidelines for carbon monoxide. Therefore, the CO emissions from the IOL Refinery Upgrade will have no measurable impact on health outcomes.

The total airborne concentration of aldehyde group of emissions and other VOCs is not expected to change significantly between the existing and the future study area scenarios, and consequently the IOL Refinery Upgrade is not expected to change the ground level air concentrations of these emissions. Furthermore, there is a significant margin of safety between the ground level air concentrations of aldehydes and VOCs measured in the community air monitoring stations and modern air quality guidelines for these emissions. Therefore, it is concluded that the available information supports the conclusion that the IOL Refinery Upgrade will have no measurable impact on health outcomes nor any accrued benefit to the public health in the community due to aldehyde and VOC emissions.

Emissions associated with the future study area scenario are predicted to increase ground level air concentrations of NO_x as much as 28.5 percent, at the stack. Even though this increase is significant, the ground level air concentrations of NO_x are projected to increase only 14 - 18.3%, and still falls well below current air quality guidelines for NOx. Therefore, it is concluded that the IOL Refinery Upgrade will have no measurable impact on health outcomes nor any accrued benefit to the public health in the community related to NO_x emissions.

The ground level air concentration of PM_{10}, $PM_{2.5}$, and TSP at the community air monitoring stations is predicted to increase under the future study area scenario. While the predicted ground level concentrations of PM_{10}, $PM_{2.5}$, TSP within the community from the future study area scenario in some cases exceeded the most stringent standard, they were less than either the Canada Wide Standard or provincial air quality guidelines for such emissions. Therefore, the available information leads to the conclusion that the IOL Refinery Upgrade will have no measurable impact on health outcomes nor any accrued benefit to the public health in the community related to PM_{10}, $PM_{2.5}$ and TSP particulate matter emissions.

Based on the comparison of the existing and future study area scenarios, the ground level air concentrations of ozone are not expected to change significantly after the IOL Refinery Upgrade. Current ambient air monitoring data from the community monitoring stations over the past several years indicate that ground level ozone concentrations within the community are less than appropriate 1-hour air quality guidelines for ozone but greater than the annual guideline. While NOx, a precursor to ozone is projected to increase as a result of the upgrade, the increase at ground level is unlikely to significantly impact on ozone production. Therefore, is it concluded that the IOL Refinery Upgrade will have no measurable impact on health outcomes nor any accrued benefit to the public health in the community due to the release of airborne emissions that can affect the formation of ground level ozone.

As discussed in detail in the Section 5.3.1, the comparison of the existing and future study area scenarios concluded that the ground level air concentrations of SO_2 at the community air monitoring stations are predicted to decrease slightly after the IOL Refinery Upgrade. Even though the IOL Refinery Upgrade is predicted to reduce the refineries SO_2 stack emissions, this reduction in airborne concentrations of SO_2 is predicted to translate into a small decrease within the community due to the small contribution of the IOL Refinery to total SO_2 emissions in the community. Therefore, the IOL Refinery Upgrade will have no measurable impact on health outcomes nor any accrued benefit to the public health in the community directly related to SO_2 emissions.

An additional potential public health issue that is indirectly related to airborne SO_2 concentrations is the importance of such emission in the formation of acidic aerosols. The various factors to be considered in the formation of acidic aerosols is discussed in some detail in Section 5.5.2. Inhalation of acidic aerosols can act as irritants and have important public health outcomes, especially for people with various respiratory conditions such as asthma, COPD, respiratory allergies, *etc*. Since the IOL Refinery Upgrade is predicted to decrease emissions of SO_2 and increase particulate, both of which are major contributors to the formation of acidic aerosols, it is estimated that the IOL Refinery Upgrade would not significantly affect the formation of acidic aerosols (Section 5.5.2). Therefore, it is not expected to affect the potential health outcomes nor provide any accrued benefit to the public health in the community related to airborne acidic aerosols.

6.3 Discussion

6.3.1 Current Public Health Status of Saint John

The overall demographic profile of the Saint John community indicates that residents are somewhat at an advantage compared to the rest of New Brunswick. The residents of Saint John have more education and higher income levels. It should be noted that there could be some distortion of these results (e.g. high levels of education and income but poorer health status) because of the difference in the geographical area compared, for example Saint John Region versus Saint John Metropolitan area.

However, socioeconomic status is just one indicator that affects the total health of a community. Other equally important factors are lifestyle factors such as diet and nutrition, tobacco and alcohol use, access to health care facilities and expertise, environmental exposures (particularly air quality), and even how the community perceives it's own health.

This perception and concern about personal health and well-being is also referred to as psychosocial factors, and is often found to be a key indicator of attitude, particularly with regard to attitudes toward health care and environmental issues. Negative effects on such factors have been called Psychosocial impacts, and have been defined as "the complex of dysfunction, distress and disability which are manifested by a wide range of social, psychological and behavioural outcomes in individuals, groups or communities as a consequence of actual or perceived environmental contamination" (Taylor *et al.*, 1997). It is recognized perceptions of environmental pollution from various types of technologically complex facilities can have psychosocial impacts on the surrounding community (Richardson *et al.*, 1987; Hertzman *et al.*, 1987; Horowitz and Stefanko, 1989; Peck, 1989; Dunne *et al.*, 1990; Lipscomb *et al.*, 1991; Shusterman *et al.*, 1991). The best examples of these have been measured near the Three Mile Island nuclear reactor (Baum *et al.*, 1983; Richardson *et al.*, 1987). Essentially, psychosocial impacts are implied to arise from the fear, anger, worry, anxiety, and stress at the individual level with resulting alterations within the social interaction network, and isolation and stigmatization at the community level (Taylor *et al.*,1997)

The results of studies by a group at McMaster University in Hamilton (Hertzman *et al.*, 1987; Goss, Giroy and Associates, 1987; Taylor *et al.*,1997) have shown that emotional stress, somatic complaints, and other indicators of psychological status, were generally unaffected by the presence of landfills or incinerators in communities in Southern Ontario. People living in close proximity to the more publicized sites did show higher levels of anxiety and worry which could be translated as indicative of a minor psychosocial impact. However, the studies were unable to identify indicators of adverse effects on health. Public awareness of a particular issue, lack of knowledge about procedures being followed result in the heightened perception of risk. These factors could have led to recall bias which may have skewed the results of studies attempting to quantify such impacts

(Roht *et al.*, 1985; Mazur, 1989) (Roht *et al.*, 1985; Mazur, 1989).

Overall, residents in the Saint John community consider themselves to be at least in good health, if not in very good or excellent health compared to other people their age (CRA, 1996). However, the project initiation meetings with various stakeholders and the general public, and contacts with the general public through the PHRA telephone line in Saint John, indicated that the people of Saint John are very concerned about their health, the various air quality issues of their community, and the phychosocial factors that can affect their health and general quality of life. The sea port in Saint John, and its location on the Bay of Fundy, have historically, and will continue in the future, to generate a significant amount of industrial activity. Saint John has a significant number of well established industries, including the IOL refinery, a pulp and paper facility, two large electricity generating facilities that provide electrical power for the province, a cement plant, a pulp mill and several other smaller industries. All these facilities on which a significant number of the people of Saint John rely for their employment, means that the population generally are very aware of the potential positive and negative impacts of industries on their community. Contacts of the PHRA team with the people of Saint John through the Working Group for the project, the public consultation meetings and the PHRA telephone response line, also indicated that the public are aware of the potential impacts of non-industrial activities, such as local vehicular traffic, residential heating and long range transport and how they affect the air quality of the community and their general quality of life.

As briefly outlined above, psychosocial effects on health are believed to be related to stress reactions resulting from people being concerned about factors affecting their lives over which they do not appear to have any control. These effects are fuelled by lack of appropriate or complete knowledge of what and how these apparently uncontrolled factors occur. To our knowledge there are no reliable methods available to quantify these type of psychosocial health concerns; however, it is well established that stress is an important factor in the occurrence of human diseases, and that psychological factors can profoundly affect the development of and recovery from a range of human diseases (CRA, 1996).

Whether or not psychosocial factors are actually affecting disease in the Saint John area is somewhat insignificant, because the communications with the public on this project have clearly shown that some residents believe such factors are important; in other words, perception is reality. In addition, such factors if sustained would affect the general quality of life of residents, and quality of life is identified as one of the environmental factors that the Province of New Brunswick requires evaluated in assessing the environmental impacts of various projects in the province. Since there is a perception within some members of the community that psychosocial impacts are occurring, it is necessary to address such effects and try to do something about them.

Since a significant factor in potential psychosocial effects on health is the perception of lack the of control over important quality of life issues an individual's life, one way of reducing such potential psychosocial impacts would be to facilitate people in controlling their lives and the environment in which they live. The very fact that this PHRA has been conducted will, in our view, assist in this regard. However, other actions could also be take, particularly related to improving communications, exchange of information and the development of increased trust and respect between the public, private sector and government. From our vantage point outside the immediate community, we see several factors that are encouraging in this regard:

i) There are a number of stakeholder organizations, many of whom we met with at the initiation of the PHRA project, that have wide representation of the public, industry and government, and who are very knowledgeable and interested in the overall environment and quality of life in Saint John.

ii) It is recognized by all the stakeholders in the community with whom we had discussions that there are unique factors influencing the environment in the Saint John region, particularly with respect to air quality, and there is a genuine commitment that these factors will be considered in developing initiatives to improve the environment and quality of life in Saint John.

It is our view that maintaining and building on the above factors will greatly assist in addressing the potential psychosocial impacts of various activities in the Saint John region. The validation section (Section 9.0) provides some ideas and concepts that we believe are important to use in building upon the already well advanced environmental awareness and stakeholder communication that exists in Saint John.

In addition, the Saint John area has been shown to have high concentrations of acidic particles relative to the rest of Canada. Local air pollution point sources in Saint John include a large petroleum refinery and two oil-fired generating stations, as well as pulp and paper mills. Together, these industries are significant sources of sulphur dioxide and reduced sulphur compounds. An article published by SM Taylor *et al.* (1997) outlines 10 "themes" that emerged as a result of in depth interviews of members of another Canadian community regarding their concerns related to a nearby oil refinery. These themes include:

- The refinery came first
- Conditions are worse elsewhere
- The refinery as part of everyday life
- Tradeoffs
- Odour perception and annoyance
- Environmental concerns
- Health risks
- Children's health
- Accountability by industry
- Trust and communications

The Saint John area is also subject to long-range transport of air pollutants from central Canada and the eastern United States (Saint John- Fundy ARMA, 1997). According to the *Perception of Air Quality in Greater Saint John Public Opinion Survey*, there are very few residents living in the Saint John area who are of the opinion that the quality of the environment in this community is excellent. Those living in areas outside the city are much more likely to be of this opinion (17%) compared to those living within the city (1%-2%). The majority of area residents consider the quality of the environment to be either good or only fair.

In order to access the current health status of the Saint John community ,data were collected from a variety of sources for cancer, asthma, COPD, endocrine diseases, heart disease, digestive diseases, skin diseases, mental health and smoking prevalence. Data for congenital anomalies were unavailable for the Saint John area. The only data found on this issue were for the entire province of New Brunswick. For this reason, and also after reviewing the risk assessment data that showed no indication of this particular endpoint, it was determined that congenital anomalies would not be examined in this assessment

Similar data were obtained from the Fredericton area for comparison. If information from Fredericton was unavailable similar data from the province of New Brunswick or Canada was used for comparison. No data were available that could be used to assess the health status of the specific communities surrounding the IOL refinery, primarily because of confidentiality issues arising from the small sizes of the populations in these communities relative to the incidence of various diseases.

Asthma prevalence was reported to be higher in the Saint John area; however New Brunswick as a whole was lower than Canada in terms of asthma prevalence. Recent findings from the Canadian Student Lung Health Survey in 1995-96 conducted by Health Canada list the most common reported asthma triggers as: colds and chest infections, exercise or sports, pollen, flowers, grass, plants or trees, tobacco smoke, dust, cold air, pets, mold/mildew, and outdoor air pollution. A total of 55% of the school children with asthma reported that tobacco smoke triggered their asthma. The *Perception of Air Quality in Greater Saint John Public Opinion Survey* reported that 63% of high school students aged 15-19 said that there was at least one regular smoker at home.

Essentially, the hospital utilization data were similar between the two groups with only the diagnosis of mental health being higher for those in Saint John. This was true only for the average number of hospital care days and was actually reversed according to hospital separations with Fredericton and NB showing a higher average rate of separations for the diagnosis of mental health. This is most likely due to the differences in access to mental health treatment and in-patient versus out-patient care between the two communities.

Higher incidence rates in the Saint John area were observed for cancers of the lung, oral cavity, larynx, stomach, liver, kidney and leukemia. Mortality rates were higher for only those cancers of the oral cavity, larynx, lung, stomach, kidney and leukemia. Both incidence and mortality were higher for males than females in both areas. Age-specific rates for lung cancer showed no differences in either incidence or mortality for any of the age groups in either area.

These data suggest that the Saint John area does have an increased incidence of lung cancer. Smoking is the leading risk factor for lung cancer, as well of cancers of the oral cavity, and the larynx. In a 1990-91 survey of over 1,000 randomly selected Saint John residents age 15 and over, 29% reported that they currently smoked cigarettes daily. According to a survey conducted by the New Brunswick Lung Association of Saint John high school youth ages 15-19, 31% were smokers. This compared with 25% for New Brunswick and 26% for all of Canada. These observations suggest that differences in smoking habits in Saint John compared to the province and the rest of Canada are important factors relative to the increased incidence of lung cancer observed.

In addition to tobacco use, diet, nutrition and alcohol consumption also play a role in influencing lung cancer risk. Prior lung disease and family history of cancer are also risk factors for lung cancer.

Studies show a lower risk of lung cancer associated with consumption of fresh fruits and vegetables, and have focussed specifically on carotenoids and vitamin C. Alcohol consumption is frequently associated with stomach cancer, cancer of the kidney and other cancers. .

Other risk factors for lung cancer include occupational factors: arsenic, asbestos, chloromethyl ethers, chromium, mustard gas, nickel refining, polycyclic hydrocarbons (PAHs), radon, and silica. Radiation is also a risk factor for both lung cancer and leukemia. There has also been concern about air pollution. The major sources of air pollution are motor vehicle exhausts, residential and commercial space heating, oil- and coal-fired power plants, and industrial emissions. Studies have shown geographic correlation with measurements of benzo[a]pyrene in air. The combination of the health risk assessment and the public health assessment demonstrates that the PAHs assessed as part of the future study area scenario would not result in measurable impacts on lung cancer. The current data suggests that the higher incidence of lung cancer observed in the Saint John area is due in part to cigarette smoking. However, smoking rates do not appear to account for all of the excess cancers, and other possible risk factors for this higher incidence rate include other lifestyle factors (as discussed later in this report), as well as other air quality issues.

6.3.2 Predicted Public Health Benefit from IOL Refinery Upgrade

In predicting the impact of the upgrade, carcinogens and non-carcinogens were examined. Carcinogens, like benzo[a]pyrene, were examined for their possible impact on cancers such as lung and stomach cancer which were found to be elevated in Saint John as compared to Fredericton. Non-carcinogens were examined for their potential impact as irritants on respiratory diseases such as asthma and COPD.

Evaluation of Potential Carcinogens

Because the incidence rates of stomach and lung cancer were elevated in Saint John and because the chemicals emitted from the refinery have the potential to cause such cancers, stomach and lung cancer were evaluated further. Although the incidence of leukemia was also higher in the Saint John region as compared to Fredericton, it was not evaluated further because of the lack of data for any incremental change in benzene. One group of probable human carcinogens associated with stomach and lung cancer identified through the US EPA are PAHs, with benzo[a]pyrene as a prime example. Therefore, the exposure to PAHs (particularly the benzo[a]pyrene group) by inhalation and orally was investigated using the results of the risk assessment and the pending incremental change. There are many risk factors involved with both stomach and lung cancer, thus a residual risk was first calculated (see Section 6.2.1). After applying the residual risk to the actual change in concentration of the carcinogens it was found that the refinery upgrade would have no measurable impact nor accrued benefit to the public health in terms of stomach or lung cancer (see Section 6.2.1).

This conclusion is further supported by the various conservative factors related to the estimation of potential health risks from PAH emissions in the future study area scenario. The concentrations of PAHs were estimated based on ambient monitoring data and predicted TSP data (Stantec, 1999b). Since ambient PAH data were used to characterize the profile, these data would include PAH from all sources, including diesel truck traffic. The IOL Refinery uses primarily fuel gas, with smaller amounts of fuel oil (diesel), as an energy source for processing. The PAH emissions from such fuels would be expected to be less than those used in the current assessment. Therefore, further confidence in the conclusion that the incremental increase in predicted PAH exposures based on the future study area scenario would not result in measurable public health outcomes in the community is given by the conservative assumptions followed in estimating ground level PAH concentrations for the health risk assessment.

For lung cancer mortality in males, the residual rate was 1.10×10^{-3}. So, 110 per 100,000 of the mortality cases cannot be explained by tobacco. The residual risk for females is 1.28×10^{-3}, so 128 per 100,000 of the mortality cases cannot be explained by tobacco. Again, the resulting slight increase in benzo[a]pyrene concentration seen in the incremental change is too small to have any affect on lung cancer mortality.

Evaluation of Non-Carcinogens

A variety of non-carcinogens were examined for their potential as irritants and their potential impact on public health in the community surrounding the refinery. These non-carcinogens were evaluated qualitatively in the risk assessment and public health assessment and include carbon monoxide, aldehydes, NO_x, PM_{10}, $PM_{2.5}$, TSP, ozone, and SO_2.

The basic conclusions regarding the potential impacts of these emissions on public health outcomes in the community were that although some changes in their ground level air concentrations were predicted to occur in the community, these changes would still result in air concentrations generally less than air quality guidelines established to protect public health, and generally within the current concentration range already experienced within the Saint John community. Based on these issues, following the established guidelines, there would be no measurable impact on health outcomes nor any accrued public health benefit to the community from the IOL Refinery Upgrade.

The ground level air concentrations of SO_2 in the community require further comment. There were a varying number of incidents at the various community air monitoring stations where the ground level air concentrations of SO_2 exceeded air quality criteria for short periods of time, and were people with sensitive conditions in the area of these exceedances they would experience adverse effects such as coughing and respiratory tract irritation. However, there are many sources of SO_2 that contribute to the ground level air concentrations observed in the community. The health risk assessment estimated (see Section 5) that the contributions of the IOL Refinery to these ground level air concentrations were historically smaller relative to other industrial sources, and that the future study area scenario indicated that a modest decrease in ground level air concentrations in the community is predicted after the IOL Refinery Upgrade.

Similar points are relevant concerning effect of the IOL Refinery Upgrade on the ambient air concentrations of acid aerosols in the Saint John region relative to those currently observed. Since SO_2 stack emissions following the IOL Refinery Upgrade will decrease by about 29%, and this will result in a small decrease in ground level air concentrations of SO_2 in the community. This reduction, in conjunction with the predicted increase in particulate concentrations, is expected to result in a small increase in airborne acidic aerosols.

Based on the various assumptions followed in the health risk assessment, the concentration of aldehydes and other VOCs is not expected to change significantly following the IOL Refinery Upgrade. Therefore, no measurable changes in health outcomes nor accrued public health benefit from the changes in these emission by the IOL Refinery Upgrade would be expected in the community. However, it is important to point out that this conclusion is dependent on the assumptions used in the prediction that the concentrations of aldehydes and VOCs in the community will not change. These assumptions should be evaluated as appropriate to test the validity of the conclusions drawn.

The stack emissions of particulate matter (PM_{10}, $PM_{2.5}$, and TSP) are expected to increase as a result of the IOL Refinery Upgrade; however, the predicted percentage increase in ground level air concentrations of these types of particulate matter in the community are less than those at the stack. This difference is related to the relative contribution of the IOL Refinery to loadings of particulate matter to the region compared to other sources. No measurable changes in health outcomes would be expected nor any accrued public health benefit in the community related to emissions of particulate matter related to the IOL Refinery Upgrade because these predicted ground level air concentrations are less than the air quality criteria for these emissions.

Overall, our conclusions from the available data are that the IOL Refinery Upgrade will not result in either measurable public health impacts or benefits in the surrounding communities.

7.0 COMBINATION OF HUMAN HEALTH RISK ASSESSMENT AND PUBLIC HEALTH ASSESSMENT

The goal of the combination of human health risk assessment and public health assessment is to provide the tools necessary to assist in the management of the health of the community. The foundation of Public Health Management Program is in the combined use of the best available environmental and medical sciences to provide proven and effective means of understanding the health status of a community, and identifying the various factors that can cause adverse effects on people's health. With this information, a Public Health Management Program can develop, prioritize and deliver appropriate initiatives to address the health issues and concerns of people in the community. This overall process effectively empowers the community to take an active role in the improvement of their health. The root of the success of these programs lies in the use of the best available environmental and medical science, and the facilitation of open communication and cooperation between people in all sectors of the community, including the general public, their various levels of government, and industry. To be successful, the process must be continuous and be adaptable over time to changing conditions and factors in the community; thus they are truly Public Health Management Programs, not projects of a 'one off' nature.

Human health risk assessments and public health assessments are two complementary and critical components of the Public Health Risk Assessment that was conducted for IOL in Saint John, New Brunswick. Human health risk assessment methods provide reliable estimates of the risks of adverse health effects in a community from a single, or any number of specified point sources of environmental input of substances (air, aqueous effluents, *etc.*). In effect, the health risk assessment methods use mathematical models to enable the separate evaluation of specific sources of exposure to people in the community. Although they provide very useful information on existing facilities, a primary strength of risk assessment methods is their ability, through the use of predictive models, to provide prospective estimates of potential risks from specific exposures in the future, even before a facility is operational and is actually releasing substances into the environment, for example, in the assessment of the IOL Refinery Upgrade which will not be operational for several months into the future. This information is valuable in the identification and resolution of problems during the design and construction of facilities, because it enables the analysis and development of appropriate risk management options to ensure a specific facility does not produce unacceptable impacts on human health or the environment after it is operational. Since a health risk assessment uses modelling techniques, the results are amenable to sensitivity analyses that can quantify the contributions of various factors to the predicted health risks. This information enables the modification of processes and implement abatement techniques to reduce risks when the facility is constructed and operating. However, since health risk assessments do not provide information about the existing health status of the community, health risk assessment modelling does not provide information that is directly applicable to the development of solutions to existing community health issues. Therefore, even though the risk assessment results provide reliable estimates of potential risks to the community from specific sources, concerns will remain in the community about the continued occurrence of health issues because of the wide array of factors responsible for human diseases.

A Public Health Assessment provides information about the public health status, issues and concerns in a community, and places a perspective on the various possible causes of, or contributors to, the current health status of the community. Health issues are a fact of life and exist in all communities. Nonetheless, it is necessary to understand the health issues of concern to both the public and health officials, their rate of occurrence and their possible causes in order to do something about them. There are a large number of factors responsible for human diseases, including:

i) genetics (familial inheritance of disease),
ii) lifestyle factors of the people (smoking, alcohol consumption, recreational drug usage, diet, amount of exercise, etc.),
iii) indoor air quality (both at home and at work),
iv) a wide variety of natural substances in the indoor and outdoor environment (naturally occurring chemicals, moulds, dusts, pollens),
v) various emissions related to general societal activities (traffic, building heating/cooling, long-range transport of air pollutants, population density), and
vi) substances entering the environment from the array of industrial activities typical of modern communities.

The combination of these two methods, health risk assessment and public health assessment, is essential to an accurate and comprehensive public health risk assessment. The interpretation of the health risk estimates from a specific scenario relative to disease incidence in an entire community requires information on the types and incidence of specific diseases in the community, and estimates of the relative risk attribution factors known to be causes of these diseases. The relative risk is an essential statistic in order to calculate the residual risk in the community. The types and incidences of diseases for different age groups and sexes are obtained through the analysis of medical records from the health care facilities in the community. Such analyses rely on statistical methods; consequently there are minimum population sizes that dictate the usefulness and reliability of such information.

Risk attribution factors for the types of diseases identified in a community are obtained from the scientific literature that report on the causal factors for the specific diseases using various types of epidemiological studies. Risk attribution techniques use the best available medical science to provide an understanding of the relative contributions of these different factors to the health issues and diseases in a community. These relative risk attribution factors of causes of disease can then be compared to the diseases predicted from exposures to chemical substances as estimated by from the results of the specific scenario risk assessment. Such a comparison enables an analysis of the relative risk contribution from chemical substances evaluated in the specific risk assessment scenario. This information, together with the overall relative risk attribution for the diseases of concern to the community, can then be integrated into a decision-making process to prioritize specific public health management options for the community that will enable future improvements in the health of the public.

8.0 CONCLUSIONS

- Based on the assumptions and procedures followed in the PHRA, no measurable adverse health outcomes would be expected in the community related to the IOL Refinery Upgrade. The counter of this conclusion is also valid. Namely that, within the proviso that the assumptions followed in the PHRA were valid and conservative such that potential health risks were not underestimated, PHRA results indicate that additional emission controls to the IOL Refinery Upgraded units, beyond those proposed, would not result in measurable benefits in the public health of the community.

- Although a number of assumptions and extrapolations were made to enable the assessment of predicted emissions by the PHRA process, the project team is confident that the assumptions and extrapolations followed were conservative in nature, and would not result in the underestimation of potential public health outcomes in the community.

- Clearly, the strength of the overall conclusion of the PHRA depends directly on the validity of assumptions used to estimate ground level air concentration data of various emissions and resulting potential risks. Recommendations for the validation of the assumptions used, and the prioritisation of this validation process are presented below in Section 9.0.

- The PHRA concluded that the ground level air concentrations in the community have historically, and will in the future (existing and future projections), exceed specific air quality objectives for SO_2 and acidic aerosols (SO_2 combined with airborne particulate matter) established to avoid public health outcomes in people exposed to such concentrations [It should be noted that there are presently no regulatory air quality objectives for acid aerosols. Rather, a provisional guideline value was derived by the PHRA study team (Section 6.5.2 of Main Report)]. The evaluation of these situations concluded that adverse health outcomes would be expected in sensitive people (*i.e.*, those with various respiratory conditions like asthma, COPD, respiratory allergies, emphysema). Such individuals would experience coughing, respiratory tract irritation, difficulties breathing, and related symptoms typical of asthma.

- The IOL Refinery Upgrade was predicted to cause a small decrease in ground level air concentrations of SO_2 in the communities surrounding the refinery because of the predicted reduction in stack emissions of SO_2. The reductions of ground level air concentrations of SO_2 were proportionately less than the percentage decrease projected for stack emissions. This observation indicates that the IOL Refinery is a smaller contributor to the ground level air concentrations of sulphur dioxide than the combination of other industrial and non-industrial sources in the Saint John region.

- Some chemicals are predicted to increase as a result of the IOL Refinery Upgrade, such as Carbon Monoxide, NO_2, and particulate matter. Neither current ambient concentrations of the combustion gases evaluated (*i.e.*, nitrogen oxides, carbon monoxide), nor predicted future concentrations of these chemicals as a result of the IOL Refinery Upgrade, would be expected to result in measurable adverse health outcomes in the community. With respect to particulate, while most ground level ambient air concentrations of particulate matter are within established guidelines, there are some values which exceed the most stringent guideline, but not the proposed Canada Wide Standard. Predicted increases in particulate matter as a result of the IOL Refinery Upgrade will result in concentrations that are either below regulatory guidelines, or concentrations which slightly exceed the most conservative air quality criteria for various sizes of particulate matter, but not the proposed Canada Wide Standard for these substances. Since many of these increases would result in concentrations that are within the range of reported values already, measurable adverse health outcomes in the community would not be expected.

- The public health assessment identified elevated risks for lung cancer and hospitalizations for mental disorders in Saint John compared to Fredericton and New Brunswick overall. The prime reasons for the high incidence of these diseases in Saint John were use of tobacco products resulting in lung cancer, and increased availability and accessibility to medical facilities in Saint John. There are residual risk factors beyond those included above for these health outcomes, and these residual factors should be investigated.

9.0 VALIDATION AND FOLLOW-UP

The compilation of a detailed validation and follow-up program was beyond the scope of the current PHRA assessment. However, some thoughts on this process have been provided to give perspective on how this process would work. The specific details of the necessary validation and follow-up step should be finalized in consultation with the various stakeholders involved (*e.g.*, industry, community, governments).

As previously indicated, the health risk assessment was conducted making a number of conservative assumptions. Also, as discussed in the introduction to the PHRA report, health risk assessment and public health assessment are most powerful in providing information for decision making if used in an iterative manner. Re-analysis of health risk estimates and public health issues are relatively straight forward once the models and procedures have been established for the initial assessment. Subsequent modifications can be assessed quickly and economically.

It is standard for studies of this size and complexity to require further validation of the various assumptions and parameters used in order to confirm the conclusions that were arrived at. Every effort was made to ensure that the data used in this assessment adequately represented conditions at the site, and that potential impacts were not underestimated. These conservative assumptions, however, do add to the uncertainty in the assessment even though they are assumptions based on best judgements and expert opinions. Validation of some of the assumptions used in the assessment will aid in "tightening-up" the results of the assessment and conclusions drawn from those results. It should also be noted that a number of these validation steps will be addressed in IOL's proposed equipment certification program and ground level particulate monitoring program. Furthermore, other areas requiring validation will be addressed as part of the conditions Irving Oil must comply with in order to operate the upgraded refinery units. For example, IOL must validate all predicted stack emissions and provide an assessment of the type, location and number of all air monitoring stations.

The recommended validation steps include:

- Verify stack concentrations of PAHs and metals are low following the upgrade
- Fugitive emissions from the IOL Refinery should be characterized for specific VOCs to enable assessment of the assumptions in the PHRA regarding these emissions (*i.e.* the VOC emissions will not significantly increase). This need not to be an extensive program. An initial characterization of the hydrocarbons from the IOL fugitive emission abatement program would provide information that would be applicable for air dispersion modelling to provide estimates of ground level air concentrations of the VOCs from this source in the community. This information could then be used to eliminate the uncertainties in the estimation of potential health risks to the community, and to address questions regarding odours. In the future, any questions regarding risks, or odours, related to fugitive emissions could be evaluated by interpolation of the specific VOC analyses with the hydrocarbon analysis to estimate specific VOCs as necessary.

- With respect to the evaluation of existing ambient chemical loads in the Saint John area, site specific ambient concentrations of MTBE were unavailable. Therefore, MTBE concentrations used in the existing ambient scenario were based on concentrations found in ambient air in 3 cities with refineries in the US. Since MTBE is a combustion product from vehicles and is used to a limited extent at the IOL Refinery, levels of MTBE in ambient air should be confirmed.

- A wide range of parameters should be monitored after start-up of the IOL Refinery Upgrade to confirm the following:

    - Stack emission rates for SO_2, NO_x, CO and TSP (and particulate breakdown); if there is a substantial change in the estimated versus measured rates for these substances then results of the risk assessment would need to be reevaluated.

    - Analyse stack emissions of TSP to characterize the PAH profile in the emissions to assess the validity of the TSP:PAH ratios used in PHRA. The conclusions of the PHRA depend on these ratios, although they were derived from ambient PAH data (including all sources of PAH, such as diesel truck traffic), and therefore are considered to over-estimate PAH emission from the IOL Refinery Upgrade. If the ratios used prove invalid, and addendum to the PHRA should be prepared using the additional information.

    - Verify ambient ground level air concentrations of SO_2 and particulate estimates once the IOL Refinery Upgrade is operational.

    - Evaluate the validity of the SO_2:NO_x and SO_2:CO ratios used, and modify PHRA as necessary (following the same rationale as outlined above for PAHs).

- An appropriate odour monitoring program, similar to that conducted historically, should be conducted once the upgrade is operational. This program should be linked and coordinated with the fugitive emission monitoring and analysis program outlined above for VOCs.

- The IOL program in place for training staff and bringing the new technologies in the upgrade on line should be communicated with the public to address concerns regarding possible failures, and resulting impacts of various kinds on the community should bringing the upgrade on-line fail.

- Due to a lack of quantitative data related to upset and accident scenarios, and the concerns raised by the public in this area, an assessment of these issues should be conducted.

- IOL should focus on improved communication with the public regarding their maintenance, and resulting emergency-response programs. Lack of information about the operation of the refinery promote feelings and concerns by the public related to lack of control over their lives, and fears about the operation of the refinery next to their neighbourhoods. These issues raise concerns of psychosocial effects on their health that then foster distrust and complaints about the operation of the refinery. The implementation of a Public Health

Management Program, as discussed below, would provide a means for improved communication with the public.

- Noise levels are not expected to change once the Upgrade is operational. However, an appropriate program, such as that conducted historically, should be implemented to monitor noise from the upgraded facility so that an appropriate noise management program can be implemented if required.

- It is not expected that the intensity of light emissions from the refinery will change once the upgrade is operational. This conclusion should be verified, and if nighttime night levels change significantly as a result of the upgrade and this poses concern to local residents, options to mitigate this problem should be identified and implemented.

- Although not related specifically to any aspects of the IOL Refinery Upgrade, it is important that follow-up from other scientific reports be undertaken, for example, historical reports with respect to the evaluation of ambient chemical concentrations and the health status of the community in general. For example a 1993 report by the NB Department of Environment and Health and Community Services examined trace metal concentrations of soil, water and vegetation in East Saint John (Pilgram and Ecobichon, 1993). The report conclusions stated that garden soils in East Saint John would be re-sampled in 5 years as a follow-up evaluation of this issue. This follow-up was not done. The lack of follow-up not only fosters distrust and frustration with the Government, it also leads to unnecessary stresses and fears of the public from lack of information on such issues.

- Although not attributable to the IOL Refinery Upgrade, risks of lung cancer and hospitalization for mental disorders were elevated in Saint John. To address these and other health issues in the community, a Public Health Management Program should be implemented in the community. The implementation of this type of program would not be IOL's responsibility. Public Health Management Programs involve the integration of the information obtained through health risk assessment models applied to various point sources, and through public health assessment (as was conducted for the IOL Refinery Upgrade) to enable the determination of the relative causal attributions of the diseases in a community. Further details of this type of program are presented in Appendix L. Other industrial, municipal and public institutions would have to be included in such a program. These sources of information, plus the specific requirements of the community, are combined to enable the development and prioritization of initiatives to improve the health status of the community. Such a program uses the results of public health risk assessment models, public health assessment of disease status and risk attribution methods to prioritize, develop and implement specific public health management initiatives.

  Examples of some public health management initiatives based on the results of the current PHRA include:

  - Smoking cessation programs, particularly targeted to the youth in the community, aimed at reducing the incidence of lung cancer in the community.

- Educational programs to assist citizens in the management of their personal health issues, such as definition and avoidance of specific triggers of asthma, management of asthma conditions, management of respiratory allergies. Such a program would improve the health status of the community, and reduce hospitalization costs associated with emergency treatment of such disease conditions when not individually managed.

- Review of access to mental health treatment and the various associated causal factors, because of the higher incidence of mental health issues in Saint John.

- Educational programs on diet and nutrition, including alcohol consumption to control the risk factors for various cancers, cardiovascular disease and general quality of life for the citizens of Saint John

- Continued, focussed, prioritized and increased monitoring of air quality in Saint John for those parameters that have historically shown exceedances of air quality guidelines (*e.g.*, SO_2 and various sizes of particulate matter).

- Ongoing surveillance of the community's health concerns, including recognition and evaluation of issues such as health outcomes believed to be related to psychosocial factors, plus asthma and other respiratory diseases, cardiovascular diseases, and various cancers.

As the Upgrade is not yet operational, validation of the predicted future impact to public health, developed though this assessment, can only occur sometime in the future. The validation of these extrapolations should be evaluated by gathering information in the future on the predicted health outcomes. To validate the predictions, collection of relevant health outcome information should be conducted after the upgraded facility is in operation. In this validation step, lung and stomach cancer as well as respiratory diseases such as asthma and COPD should be monitored. Scientific literature, hospital separation data, and incidence and mortality rates would be evaluated.

The necessity for this type of follow-up on lung cancer and respiratory diseases could be judged based on the results of the various confirmatory monitoring programs discussed above. For example, if the emission verification recommendations indicated that the PAH concentrations used in the current PHRA were equal to or greater than those actually measured, it would not be necessary from the point of view of the IOL Refinery to expand the monitoring of lung and stomach cancers in the community. However, since the public health assessment indicated that these particular diseases were elevated in the Saint John area, it may be important as part of a public health management program to continue monitoring such diseases to enable measurement of performance of other intervention programs that would not involve the IOL Refinery.

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APPENDIX A

PUBLIC CONSULTATION

A-1.0 PUBLIC CONSULTATION

A-1.1 Introduction

A prime focus of the Public Health Risk Assessment (PHRA) was to ensure members of the local community had an opportunity to express their concern regarding the IOL Refinery Upgrade, and participate in the assessment process. A variety of methods, summarized in this Appendix, were used to facilitate and encourage public input on the project. These included meeting with key stakeholder groups, holding a public drop-in session, maintaining a community response telephone line, web site address, e-mail address and local post office box where community members could provide their comments, questions, *etc.*, related to the upgrade to a study team member (for more details refer to Section 3.0 of the main report).

A-2.0 STAKEHOLDER MEETINGS AND PUBLIC DROP-IN SESSION

As part of the public consultation activities for the Public Health Risk Assessment of the Irving Oil Refinery Upgrade, a number of key stakeholder meetings were conducted including meetings with the following groups:

- Air and Resource Management Committee (ARMA)
- Citizens Coalition for Clean Air
- Department of the Environment (Saint John)
- Irving Oil King of Cats Project Community Awareness Liaison Committee

During these meetings, notes were compiled by Northcote Group to document the stakeholders comments and concerns. While not all issues discussed at the meetings were directly related to the refinery upgrade or the refinery itself, they are included in the meeting notes as documentation of the issues discussed. Neither CANTOX ENVIRONMENTAL INC., HRMG nor Northcote Group expressed any comments regarding agreement or disagreement with information or feel it is accurate or inaccurate. The sole purpose was to gather information on public concerns to facilitate the planning of the assessment. Details of meetings with stakeholder groups are provided in Sections A-2.1 to A-2.4. Meeting participants commented on meeting notes to ensure the information was accurate and reflected what was discussed.

A 'public drop-in' was held on May 27th at the Forest Hills Elementary School, which provided individual members of the community with an opportunity to ask questions, register concerns and provide input on the assessment to study team members. A summary of this event is presented in Section A-2.5.

A-2.1 Summary of Meeting with Members of the Former Saint John ARMA Committee

Four former ARMA committee members attended the 1½-hour meeting held at 2 p.m. at the Trade and Convention Centre on Wednesday, May 26, 1999 including: Claude MacKinnon, City of Saint John; Gerald Babineau, citizen; Don O'Regan, Moosehead Breweries and Colleen Lang, citizen. The Study Team members involved in the discussion were Dr. Bob Willes and Lisa Marshall of CANTOX ENVIRONMENTAL Inc., together with Dr. George Carlo and Becky Steffens of Health Risk Management Group. Christene Matthews-Celeste attended on behalf of the Northcote Group.

The meeting began with initial questions about the operational changes expected at the Refinery in connection with the Upgrade. An introduction and detailed discussion on the Public Health Risk Assessment for the project followed. The group reviewed a variety of issues in detail, including questions on how the different risk assessment and health assessment components will apply to this specific study, and how any gaps identified during the process might be addressed through a future Public Health Management Program.

Specific points raised during the meeting by various participants included the following:

Overall Assessment Process

- It was explained during general discussion that the study as a whole was not intended to "point fingers" at a specific emission source other than those associated with the IOL Refinery Upgrade. A more detailed analysis of the entire airshed, and other potential contributions from other human activity and/or specific sources in the area concerned would be required to address broader issues beyond the IOL Refinery Upgrade.

- It was also noted by Study Team members that past studies in this area have not included both risk and public health assessment components. The combination of both components is considered vital to a complete assessment. The Study Team explained that risk assessment modelling methods provide a predictive tool while the health assessment provides an analysis of the current health status of the community. The two approaches together enables a more comprehensive assessment.

- Some participants from the ARMA Committee expressed the view that determining what a particular source may be contributing to local pollution represents a lesser concern, than the broader need for 'clean air' in the Saint John area. In discussion, it was also noted that the assessment should not be seen as a study which will conclude by prescribing solutions to diminish the incidence of disease, such as asthma, for example.

- **Public Health Management Program** - Should the health assessment in this case ultimately conclude that there are adverse health effects arising in the community, but that the Refinery is not a major contributor to such impacts. Tackling the issues involved would require a much broader community focus, such as a comprehensive airshed Public Health Management Program.

- **Data Concerns** - It was pointed out by some ARMA representatives that many people tend to look for definite conclusions based on study data, which are often very difficult for the authors concerned to make.

  It was also noted that some people in the community tend to accept the assertion that 'puffer' use is more prevalent in the area, without taking into account the fact that local physicians might be more apt to prescribe them these days, whether it's a necessary solution to an individual's health concerns or not.

- **Validity/Value of the Assessment Study** - Questions about the intentions and value of the Public Health Risk Assessment, were raised on several occasions. Study Team representatives explained that the Refinery's present construction project received approval from the Province, subject to a number of conditions, one of which is completion of a 'public health risk assessment' on the 'Upgraded' facility. It was also emphasized that this study "in itself" is a step forward for the community as a whole, showing that "Irving" is 'standing-up and taking notice' on such issues. Some ARMA members felt that no matter who pays for the cost of the assessment, certain members of the community would only believe the final report if it supports their position. If it doesn't, then they won't support it.

  The Study Team responded by stating that either way, their continued success as companies in this field depends upon providing unbiased scientific results. In other words, "they can only go with the facts".

  ARMA Committee representatives noted as well that such assessments are a snapshot of a particular time and, as a result, follow-up studies are important. Although not part of the present scope, the design of a validation program is part of the Study Terms of Reference and will allow for validation of the assessment results.

- **Psycho-Social impacts** - There was some discussion on how psycho-social impacts can be addressed by this Assessment. The Study Team has addressed this issue in other areas, and stated that ignorance or fear of the 'unknowns' in such a situation are the greatest contributors to psycho-social impact. It was agreed that there is a need for greater openness from the local industrial community and continued education, as well as participation, on the part of the public. This assessment is one of the first steps in that direction. One participant felt that, at the present time, residents in the community were more concerned about immediate impacts of noise and dust, rather than longer-term health issues.

The Study Team stated that, as part of their Terms of Reference, they do have to look at noise and odour related to the upgrade operation. Concerns about construction noise in particular, will be passed onto DOE and the Irving Refinery.

- **Odour -** It was stated by one ARMA member that the 'Bunker C' smells are both worrisome and unacceptable. The Study Team observed that it's possible that an odour control program could be developed, but this was beyond the objectives of the current assessment. In such a process, odours would be separated into groups which represented either health risk or nuisance issues, and dealt with accordingly.

Other Public Concerns

- **'Upset events' -** The topic of air emissions during 'upsets' was raised as a major issue of concern for the public. However, ARMA Committee representatives expressed the view that 'upsets' are facts of life. They suggested that Irving should explain more fully to the public that the Company monitors its equipment very closely. In one case, for example, an event showing up in internal IOL monitors was detected and the Company quickly contacted NB DOE to report what had taken place. The Study Team stated that in their experience, companies should expect to have fewer upsets with this new type of technology, as well as better control in restarting production after a shutdown.

- **Public Participation and Public Understanding -** The interest level of the public in the Upgrade project was discussed and it was recommended that information should be actively distributed to people who wouldn't normally be looking for it. The invitation to the public drop-in, availability of the community response phone line, acceptance of written comments at the local postal box or web site and the plan for future newsletter distribution were underscored as specific steps incorporated in the process aimed at encouraging active public consultation.

  Some ARMA Committee representatives stated that there is a gap in public understanding in regard to all development projects. "On the one hand, people agree that something has to be constructed but then complain that their neighbourhood is being ruined, if there's noise, dust, truck traffic, *etc*. They don't accept that is this what occurred in the past when their own house was built. Such complaints are becoming more and more prevalent."

A-2.2 Summary of Meeting with Members of the Citizens Coalition for Clean Air

Twelve members of the Coalition attended the two-hour meeting held at the New Brunswick Community College on Tuesday, May 25, 1999 including: Gary Prosser, Joanne Evans, Lloyd Evans, Connie Richard, Ed Richard, Aubrey Fougere, Muriel Livingstone, Anne Kingston, Lou McIntyre, Keith Broadbent, Bob Kirkpatrick and Rhoda Kirkpatrick. Study Team members attending included Dr. Bob Willes and Lisa Marshall of CANTOX ENVIRONMENTAL Inc., Becky Steffens with Health Risk Management Group, and Christene Matthews-Celeste on behalf of the

Northcote Group. Comments on behalf of the Coalition were received prior to the meeting from Gordon Dalzell *via* fax.

The meeting began with an open discussion on what the Public Health Risk Assessment for the Refinery Upgrade will entail. As the meeting progressed, both general and specific statements or questions were raised about the health impacts of air pollution in Saint John.

The Study Team began by explaining that a Public Health Risk Assessment is a scientific study of the possible risks of adverse health effects from specific emissions. These potential risks are put into perspective by evaluating the public health status of the community potentially affected by the emissions.

A background information sheet on the Public Health Risk Assessment was distributed to all participants at the meeting, who were also notified about the project's 'Community Response' local phone line, which is available to take their input and/or questions and provide a detailed response in each case.

Some participants expressed skepticism about the validity of the study; its results; what if anything it would accomplish; and what organizations would be supporting it financially. Some skepticism was expressed as to whether the assessment data could be 'manipulated' for the benefit of those actually paying for the project. The Study Team explained that this assessment process was in part the result of public demand for such a study and response to that demand by the concerned Provincial regulatory agencies. The Study Team's mandate is to provide an independent scientific study. The project will be initially funded by the Department of Health and Community Services and the cost will then be recovered from Irving Oil Limited.

Clear interest was expressed by the participants in being involved with the public consultation component of the study. They also welcomed any recommendations that could be made to prevent potential human health impacts from the 'Upgrade'.

The Study Team stated that some issues would be addressed quantitatively, while others will need to be addressed qualitatively. All issues identified, however, would be helpful in the planning and implementation of the study. It was noted as well, that the assessment would not answer all "air quality" questions in the City of Saint John. The possibility was raised that development of a larger Health Risk Management Plan could be undertaken in the future to deal more fully with some of the issues concerned that are not related to the refinery upgrade.

Major issues of concern identified by Coalition members during the discussion included the need to assess potential impacts and mitigative measures for 'upset' conditions including duration and frequency (*e.g.*, start-up, shut-down, maintenance, accidents) for the 'Upgrade'. In addition, the coalition indicated the need for 'point source' monitoring. The different types of pollutants to be included in the study; how the data will be assessed; what are the present and predicted impacts of odour and noise; and the increasing rate of respiratory-related problems locally were among the major issues raised by the Coalition members. Coalition members were told that the Study Team's present Terms of Reference did not specifically include 'upset' conditions, but these issues will be addressed at least qualitatively, with the possibility of being examined in a quantitative fashion as part of a later study if required. Specific comments and points raised during the meeting by Coalition members included the following:

Specific Comments:

- Concerns were expressed about what type of data would be included in the assessment, *i.e.*, just airborne health risks?; noise?;odour?; heavy metals?; trans-boundary pollution? As well, participants questioned where the data would be coming from and if Irving data will be used. The Study Team stated that background ambient concentrations would also be evaluated to assess exposures of people to total sources of emissions, including those not related to the Refinery (emissions arising from other human activities, other industry and natural sources).

- The concern with potential effects to well water was raised (in the Red Head area) and it was felt by some Coalition members that the collection of well data may be useful. The Study Team noted this concern for discussion with the Working Group.

- Some Coalition members indicated that 'Point Source Monitoring (right on the stack) is what's needed. This way the emissions could be controlled before they get into the community. It would also give a true picture of what the facility is emitting and what it might expect to emit in the future.' Coalition members pointed out that a 1989 report, "A View of the Saint John Air", already stated that point source monitoring was needed. It was noted that the US requires mandatory monitors on smokestacks at waste facilities, not refineries or power plants.

- Concerns were expressed about the potential harmful impacts of odours, specifically in the Grandview Avenue area. These odour concerns related particularly to heavy and light oil smells. The Study Team noted that odour would be addressed in the study. Odours from the wastewater treatment system were also noted as being offensive.

- The most common health concern identified by those in attendance was asthma. There were a number of concerns about the increasing rate of puffers being used in the area, particularly by children. Some participants noted that an informal study using data from local pharmacies had been carried out. Concerns about the cancer incidence rate in the area were also expressed. A recommendation was made to use Champlain Heights as a control group for a disease comparison study. The Study Team indicated that for the present study, available data would be used to assess potential health impacts rather than conducting door to door health surveys in the community.

- Participants expressed concerns about how 'corrosive' the air is in East Saint John. Outdoor brass fixtures being pitted, exterior paint chipping, "dandruff" landing on vehicles and patio furniture, as well as other incidents were cited as examples of this problem.

- Other concerns related to the number and types of chemicals which will be included in the assessment. Specifically, participants want the assessment to analyse the particulate for heavy metals, PAH's, and toxic materials. The assessment also needs to provide complete health impact analysis from those pollutants known to be emitted from refinery into ambient air, such as: carbon monoxide, nitrogen dioxide, sulphur dioxide, hydrogen sulphide and particulates. The Study Team indicated that these factors would be addressed in the assessment.

- It was recommended examinations occur during both the day and evening, and that the emissions be assessed on a seasonal basis. It was noted that data covering such conditions are available. It was also pointed out the study must respond to unique set of air quality conditions and special circumstances found in the community. The high incidence of temperature inversions was noted, as well an occasion when the pH level of local fog was measured at 4. These issues were noted by the Study Team for inclusion in the assessment.

- One question raised during the discussion asked whether the Health Risk Assessment will follow the US ATSDR Public Health Assessment approach. Participants were told that Dr. George Carlo who heads the Health Risk Management Group was one of the authors of the ATSDR document (which has been updated) and the assessment would follow this approach.

- Some Coalition members indicated that the "tubes and piping" of the cracker units were scoured with silica sand during the night, with releases directly into the environment. Concerns were expressed regarding 'what substances would be in the material scoured from the plumbing?' The Study Team indicated they would look into this issue further.

- Will the proposed pollution control/prevention equipment be sufficient to cut down dangerous emissions to ensure public health safety? The Study Team noted that the predicted emissions from the "King of Cats" would be included in the assessment.

- Construction concerns included noise, particularly from pile driving. The loss of aesthetic enjoyment of their property and physical environment from noise and exhaust emissions was also expressed. The Study Team responded that construction concerns would not be addressed in the assessment but would be passed on to the DOE and the Irving Oil Refinery. However, issues such as noise, odour, *etc.*, associated with the Upgrade operation would be evaluated.

- Concern was also expressed that the new technology to be used may not have been adequately tested. Participants questioned whether it had been used elsewhere, and if it would work. They noted the continual loud noises associated with an earlier upgrade (sounded like an air plane taking off) when a muffler system had to be installed. They want assurances that the new upgraded system will work. The Study Team noted this issue for inclusion in the assessment.

- One Coalition member stated that for a long period, the Irving Oil Refinery buried their spent catalysts right on the refinery property. The concern was expressed that many such materials are considered carcinogenic.

- Participants raised the issue of identifying a "canary" or environmental sentinel that could be used as an early warning system of impacts from the refinery. The Team discussed their experience in this area, using small rodents such as shrews, as environmental monitors.

- 'It should always be recognized that the location of the refinery is in a vulnerable airshed, in the middle of a city, among residential homes and businesses.' The Study Team noted that these parameters will be considered in the assessment.

- It was stated that the best natural defence against air pollution is trees, and yet trees are being cut down behind Champlain Heights for the (realignment) of the Refinery's water pipeline. It was stated that there will be more impact on air quality because of the loss of this buffer zone.

- Concerns were expressed regarding the possible impacts of emissions from the refinery on plants and vegetation in the area. Participants noted that garden soils which were supposed to be re-sampled within 5 years (as recommended in a 1993 study by the NB Departments of Environment and Health and Community Services) hadn't been. It was recommended that another soil study be carried out. The Study Team indicated that these issues will be discussed with the Working Group.

- A number of exposure pathways were identified including: 'homegrown' vegetables. One participant noted that 30 to 35% of his yearly vegetable intake came from his garden. The largest garden in the area is owned by an elderly gentleman on the Red Head Road.

- Fishing – Shad and Gaspereau are fished from the harbour area and sold at the Saint John Market. A salmon farm is located in Drury's Cove. Participants referred Team Members to a mussel toxicity study done at UNBSJ.

- Hunting – Recreational hunting, specifically moose and deer, occurs in the surrounding area.

- Berries – Blueberries and other types of wild berries are picked in the surrounding area.

- Participants referred Study Team Members to a report carried out by Dr. Pengelly of McMaster University. They also recommended team members speak to Dr. Beveridge.

Key Issues and Concerns of the Coalition:

Coalition Chair Gordon Dalzell submitted a seven-page report to CANTOX ENVIRONMENTAL *via* fax prior to the Coalition meeting, highlighting the key issues and concerns of the Coalition. He also provided the Study Team with several scrapbooks of news clippings and information regarding air quality and environmental issues in Saint John (including many articles specifically on events related to the refinery over the past several years). Mr. Dalzell's report is as follows:

CITIZENS COALITION FOR CLEAN AIR

KEY POINTS TO BE STUDIED FOR THE PUBLIC HEALTH RISK ASSESSMENT

HIGHLIGHT OF ISSUES/QUESTIONS/ISSUES OF CONCERN

INTRODUCTION

In April 1, 1998, the Citizens Coalition for Clean Air identify need to assess health effects and impacts from the expanded Refinery in terms of the toxic chemicals found in, and associated with, the manufacturing of petroleum products in the Irving Oil Refinery. Our position is clear - any Environmental Impact Assessment determination needs to include a health risk and health study assessment with recommendations.

Our community group was pleased to see a Public Health Risk Assessment as one of the 11 conditions issued by Minister of Environment in August, 1998 under the Certificate of Determination of Environmental Impact Assessment.

In respect to this issue, our rationale for this recommendation is based on the fact that:

1) this Refinery soon to be upgraded and expanded, already the largest in Canada, is located in:
   (a) a vulnerable airshed
   (b) the middle of a city near residential homes and business, retail centres
2) has been the centre of a number of air quality emission events over the years (see scrapbook)
3) has, by the nature of the manufacturing process, a wide range of various pollutants, including volatile organic compounds (VOC's), including organic chemicals.

Our research concludes that petroleum products are dangerous to our health. even in small amounts. These toxic chemicals such as xylene, toluene, or benzene, can be absorbed into our bodies where they can affect different areas. Our research references indicate that those chemicals can affect our brains, liver or blood cells. Some of the petroleum products can even cause leukemia and other types of cancer or birth defects.

(Ref: "Health Effects of Petroleum Refineries" Principal investigator, Professor Jeremy Richards, UNB and Mr Jean Marie Golsse, UNB.)[1]

This study focuses on oil refinery workers who are exposed to over 1000 chemicals, many of which are known to have adverse health effects, and some of which cause cancer.

This facility soon to be upgraded, in our view, presents important concerns and issues in terms of these chemicals finding their way into the environment and impacting on thousands of people, even within the ambient air. For example, there have been incidents of significant dust particles emitted, causing the City of Saint John to issue an advisory not to eat garden vegetables unless washed. Other times, dust-like materials were emitted onto homes, cars and the Refinery arranged to have people's cars, homes washed (see scrapbook). These fine dust materials, some so fine they cannot be seen, enter the body directly into the airways. We want assurances and this study/assessment to analyze the particulate for heavy metals, PAH's toxic materials. What is the risk to health in Digesting these materials? Over the years, particulate PM 2.5 has been a hazard from this Refinery.

There has been this comparison made that the Oil Refinery emissions are equivalent to 25,000 cars idling all at once in one day. This may be a myth but it serves to illustrate the fact of significant emissions from various sources such as NOx, VOC, S02, particulate, *etc.* The document "Work is Dangerous to your Health" by Jeanne M. Stillman, PhD, Susan M. Davum, MD describes principal petroleum products such as silica alumina (catalytic cracking dust).

We recognize that what is in the ambient air in nearby residential areas may not be at same level as if one was working directly around those materials but our neighbourhoods are extremely close and thousands of people are vulnerable, such as infants, young children, seniors, those with existing respiratory conditions, such as asthma, *etc.*

This Health Risk Assessment has to customize its study to respond to the unique set of air quality conditions and special circumstances found in our community. (See ARMA March 1996 Report)

Apart from the above concerns about the toxic pollutants within the VOC group, the risk assessment needs to provide the public with a complete health impact analysis; impact from those pollutants we know for sure that are emitted by this Refinery into our ambient air supply, such as carbon monoxide, nitrogen dioxide, sulphur dioxide, hydrogen sulphide, pollutants that contribute to ozone smog formation, total suspended particulate (TSP) and inhalable particulate (PM10, 2.5 microns or less), which bypass filtration in the nose and are deposited in the lungs.

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[1] **It was brought to the attention of the study team that Professor Jeremy Richards and Mr. Jean Marie Golsse are not, and were never professionally associated with UNB.**

We have high expectations that this Public Health Risk Assessment will carefully study health impacts, past and future projected emissions data from the upgraded refinery.

In our view, one cannot analyze health risk by just restricting oneself to future projected analysis of data. You need to study the emissions levels, impacts over the last 40 years since the facility opened in 1959-60.

For example, based on total emissions from those pollutants, what impact was there -to human population based on our modern understanding of the health impacts such amounts would have on the environment and health?

What we would like to see is a health study analysis of health impact data such as diseases/conditions found in Saint John compared to other cities that didn't have an oil refinery.

If you ask people in Saint John whether they believe rates of cancers, birth defects. respiratory conditions are higher here than other parts of New Brunswick or Canada, many would say yes. We would like this Risk Assessment to carefully analyze the health stats re higher or lower levels of those diseases here in East Saint John, particularly those surrounding neighbourhoods around the oil refinery.

Any myths, or misinformation Deeds to be clarified. Hopefully, this assessment will clarify these issues and concerns re higher incidence of health problems directly related to the Irving Oil Refinery.

Will the proposed pollution control/prevention equipment be sufficient to cut down dangerous emissions to ensure public health safety?

We recognize that the Refinery will be spending $100 million on all environmental improvements. How much on air pollution control technology? Any more needed? Hopefully, this study will make recommendations as to what further must be done to protect human health.

Please refer to "A Report on Air Quality Monitoring Results in New Brunswick for the years 1996-97 Dept. of Environment".

OTHER ISSUES/CONCERNS:

Mental Health Impact under Health Risk Assessment Terms of Reference

- Impact of noise from pile driving.

- Impact re loss of aesthetic enjoyment of our physical environment, from smoke, steam, construction activity, *etc.* Just driving down Grandview Ave. from Champlain Heights looking at this industrial complex is intimidating and often causes anxiety, thinking about explosions (June, 1998), fire or other catastrophic events associated with the Refinery. This complex is taking up more area of our community.

- Please research physiological, mental health references in respect to mental health impact.

- When analyzing the risk it is important to keep in mind that many people work shiftwork, have to come home and sleep various times. This facility with its expansion and new equipment could have noise impacts, especially at lower end of Grandview Ave. near Midwood Ave. neighbourhood. This whole area needs to be analyzed.

- Impact on human health has to include area of situations where a person has a high-stress job, may have high blood pressure and cannot "relax" or rest properly because of the Refinery activities. This could affect a person's health and theoretically, the person could die from a stroke, heart attack, *etc.*

- These are the day-to-day real concerns people have living next to the largest oil refinery in Canada.

- This Public Health Risk Assessment has to be aware of, and zero in on, real life health impacts, risk analysis associated with the expanded Refinery.

- Diesel emissions associated with truck, equipment use during upgrade. According to our research, evidence has been accumulating that the greatest hazards associated with diesel engines is in their exhaust; specifically, in the potential for diesel exhaust to cause cancer. Diesel exhaust has been shown to cause cancer in laboratory animals, and epidemiological studies have suggested the strong possibility that it causes cancer in humans. [See reference "Carcinogenic Effects of Exposure to Diesel Exhaust", The National Institute for Occupational Safety and Health (NIOSH).]

Issues from-Environmental Health and Safety

From a public health perspective, one needs to focus attention on preventing or at least minimizing potential human health risk.

The Dalhousie Study, June 10, 1998, states "The use of annual mass emission figures may not be very helpful in assessing the public health effects of our emissions".

We would suggest that the results of stack monitors or continuous emission monitors (CEM) be used to give you a true picture of what that facility has emitted and will be expected to emit in the future.

Additional Point/Recommendation

We want to see the various issues and questions addressed by Dr. Joan Campbell, such as:

"This health risk analysis should include health outcomes associated with ambient levels of pollution in Saint John, including respiratory illness, hospital admissions, premature mortality, as well as possible work-related cancers among IOL workers".

There are many comments raised in this Dalhousie Study that we expect to be addressed in this Health Risk Assessment in order to reassure the public's concerns and fears.

Further comments and recommendations (by Dr. Judy Guernsey Dalhousie Study) should be followed:

"This reviewer recommends that this health impact assessment be organized and presented in accordance with the U.S. CDC's ATDR Public Health Assessment Guidance Manual (ISBNO-87371-857-7). Lewis Publishers CRC Press, Boca Raton, Fl., 1993".

Will this Health Risk Assessment follow that format and process?

"Exposure pathways to the community and to -the workforce should be described it."

Thousands of people are, and will be, constructing this upgraded facility; they live in, and are part of the community. One cannot separate occupational health impact from the overall general community impact.

The Health Risk Assessment has to include analysis on possibility of mishaps and malfunctions, such as the case last June, 1998 where a fire and explosion occurred.

This Health Risk Assessment must not just focus on sulphur oxides as noted above. VOC's, heavy metals (mercury, lead, cadmium, *etc.*). PAH's present in oil residues are well known carcinogens. In the EIA application there was no discussion provided about how these materials will be managed.

Such materials as aliphatic amines, caustic soda are well known irritants. Inadvertent leaks of these agents into the air or water of community may present a health risk. Similarly, protection from inadvertent release of acid aerosols into the community environment should be outlined and health risk analysis completed.

Another Issue:

We want this Health Risk Assessment to do an analysis of trace metals content of vegetable gardens, soils and surface waters in East Saint John.

We would like to see garden vegetables assessed to determine health risk of eating from our gardens.

Reference "an Analysis of the Trace Metal Content of vegetables Garden Soils and Surface Waters in East Saint John following an Atmospheric Deposition of Particulate" (DHCS Oct. 1993).

One of the recommendations of that report was "garden soils in East Saint John will be re-sampled in 5 years".

You need to get this follow-up study if it was done.

Issue of Odour:

There is a persistent heavy petroleum odour picked up along Grandview Ave. from a "hot oil tank" with a floating roof that emits offensive odour.

We want this Public Health Risk Assessment to look into issue of odour from an overall health risk perspective. See report "Preliminary Ambient Odour Survey", DOE, Jan.10, 1995 by Orteck.

These issues are an overview of some of the issues we want to see covered in this Health Risk Assessment. I will be pleased to share resource materials compiled in preparation for this kind of Health Risk being commenced.

In our view, a Public Health Risk Assessment value is dependent on and related to the kinds of questions asked as well as the right kind of data being analyzed.

We welcome this assessment particularly any recommendations made to prevent human health impact of this Refinery upgrade.

Sorry I personally could not be Present tonight as I am in Calgary participating in national consultation meetings for new Canada Wide Standards for Ozone and Particulate.

Trusting these points, along with ones identified tonight, be of help in your important work.

Sincerely,

Gordon Dalzell, Chair Saint John Citizens Coalition for Clean Air
May 25. 1999

A-2.3 Summary of Meeting with the NB Department of Environment - Saint John Office

Six people from the Saint John Regional Office of the Department of Environment attended a meeting on Wednesday, May 26, 1999 to discuss the PHRA including: Susan Atkinson, David Roy, Patrick Stull, Jim Maber, Krista Powers and Tara Savage. Study Team members attending the meeting were Dr. Bob Willes and Lisa Marshall of CANTOX ENVIRONMENTAL Inc., and Becky Steffens with Health Risk Management Group. Christene Matthews-Celeste attended on behalf of the Northcote Group.

The meeting began with a summary explanation by Study Team representatives describing the Public Health Risk Assessment for the IOL Refinery Upgrade and a general discussion about possible sources for the data, required in connection with this assessment.

Comments on the primary public issues identified thus far and the problems that may arise during the process were discussed as well.

Points raised during the meeting by the participants included the following:

Odour Data - For the past five years, local DOE personnel have undertaken a daily tour of the perimeter surrounding the major industrial facilities in East Saint John. Approximately 12 locations are checked daily, with wind direction, stack plumes and noise levels recorded. The route begins at the front of the Courtney Bay Generating Station; continues to the corner of Grandview Avenue; to Red Head Road; then to the top of Midwood Avenue and the Irving Lagoon located near the railway crossing. The route continues on Industrial Drive past the Allied Van Line/Movers facility, to the top of Grandview Avenue and onto Champlain Heights Drive. It proceeds through the traffic circle in front of the school, continues past the Champlain Heights Irving Station and St. Joachim's Church to the top of the hill near the refinery's main entrance. The final stop is on MacDonald Avenue near the Sobey's end of the Loch Lomond Mall. The resulting data compilation, which has been updated to include 1998, will be made available to the Study Team.

Standardized odours recorded include petroleum hydrocarbon odours, sewerage and pulp mill smells to 'outfall odours' from the Courtney Bay Generating Station and the flats associated with that facility. It was stated by DOE staff that a 'heavy oil' odour is more noticeable in the area now, than was the case several years ago.

Noise - Construction noise stemming from the Upgrade project began near the end of March/beginning of April. The present conditions of approval allow pile-driving to take place from 7:30 a.m. to 6 p.m., Monday to Friday, and Saturdays if deemed necessary. Since April 21st, no pile-driving has taken place on Sundays. DOE stated that the Irving Group has done a study on noise which should be available to the Study Team.

Air Emissions & Monitoring - The document "A Report on Air Quality Monitoring Results in New Brunswick for the Years 1996 and 1997" was provided to the study team. Air quality data and monitoring locations were discussed.

Data issues - The Study Team discussed with DOE potential areas where soil data could possibly be located. Based on discussions it appeared that local soil data are limited. The metals study in Champlain Heights was mentioned. It was suggested by DOE that metals-oriented maps could be accessed from NB DNRE in Fredericton. DOE supplied CANTOX with a study report containing follow-up data from soil samples collected after the 1998 explosion at the Refinery Site. The Study Team was also referred to the Fredericton office of NB DOE for additional data.

Upset Conditions - It was agreed that while any impacts in such a situation are of short duration, they could have the potential to be significant. The question of how an 'upset' should be defined was raised for discussion and DOE wondered how this has been handled in other settings.

The Study Team explained that, although upset conditions were not specifically included in the Terms of Reference, it might be possible to include this subject area as a separate assessment or an addition to the current assessment as part of final recommendations. This issue will be brought to the attention of the project Working Group for consideration. DOE recognized that upset conditions could be an area that requires future assessment.

Other public concerns discussed - The Study Team discussed the public's apprehension towards the new technology at the refinery. It appears that some are fearful that the technology may not have been adequately tested or could generate loud noises. DOE staff asked whether data from that particular refinery could be used to measure the impact of upsets at IOL in Saint John.

Concerns were expressed regarding the "enjoyment of property" as many trees in the area have been cut down, removing any effectiveness they might have as 'natural filters', especially for noise and aesthetic considerations.

Assessment studies - It was asked whether IOL would be supporting any more scientific studies down the road. The Study Team felt that results of this assessment may lead to the need for further studies for Saint John in general (not necessarily related to the refinery). The possibility of implementing an Air Shed Public Health Management Program was discussed. It would look at the total health of the community and deliver a risk apportionment for such risk factors as genetics, lifestyle factors and indoor and outdoor air quality. The Study Team felt that the empowerment of the community through such a process, on all the issues surrounding public health, would have a positive impact on the health of the community, and on the promotion of greater cooperation and understanding between the community and industry in the area. DOE felt this type of future study would make sense.

DOE Concerns - Psycho-social concerns and the loss of enjoyment of property were recognized as real concerns and difficulty in dealing with these concerns was expressed. The Study Team indicated that these factors will be addressed qualitatively in the assessment, but that it is doubtful if sufficient information will be available to quantify such issues.

Issues concerning the public participation in environmental issues were also discussed. The Study Team noted that more public involvement generally leads to less anxiety on the part of the community, and is critical to ensuring that the concerns of the public are addressed in the assessment.

DOE wanted to know what results and recommendations have been generated from other similar projects. The Study Team briefly discussed work conducted on petroleum refineries in Western Canada, noting their similarities and differences with the IOL Refinery Upgrade.

The importance of local ambient forecasts now available for local residents was discussed. The Study Team noted that such forecasts in other locations have proven useful in allowing some people to adjust their lives so as to better manage their medical conditions. In fact, ambient forecasts may result in significant savings to the cost of health care, since it's cheaper to manage one's health condition outside the emergency room. An economic study on the potential savings of local ambient forecasting was suggested.

Other data available:

- Database of complaints concerning the Irving Oil Refinery can be made available to the Study Team at any time.
- Air quality index values are available on the DOE's web site. The service provides both forecasts and alerts. A number of local residents with health conditions rely on this kind of information.

A-2.4 Summary of Meeting with the Irving Oil King of Cats Project Community Awareness Liaison Committee

Eight individuals from the Community Awareness Liaison Committee attended a two-hour meeting held at the Trade & Convention Centre Wednesday evening, May 25, 1999 including: Wayne LeBlanc, Doug Myers, Brian Roy, Warren and Laura Van Wart, Peter Friars, Muriel Livingstone, and Claude MacKinnon. Study team members attending included Dr. Bob Willes and Lisa Marshall of CANTOX ENVIRONMENTAL Inc., Dr. George Carlo and Becky Steffens with Health Risk Management Group, and Christene Matthews-Celeste on behalf of the Northcote Group.

The meeting began with a general introduction on what this Public Health Risk Assessment will involve and what the Study Team expects to accomplish. A variety of issues and questions concerning air pollution impacts in Saint John were raised during the ensuing discussion.

Clear interest was expressed by the group in participating in the public consultation component of the study. They also welcomed any recommendations that would be made to ensure that the potential human health impacts that may be associated with the upgrade will be evaluated. A background information sheet on the Public Health Risk Assessment was distributed to those in attendance. Participants were also notified of the community response telephone line now available to enable them to provide input into the assessment and to express their concerns.

The Study Team made it clear that issues could be identified during the health study which are community-wide in scope and may not have any relation to the refinery operations. Those at the meeting were cautioned about having unrealistic expectations from the current assessment. The current study has specific objectives focussing on the upgrade of the Irving Refinery. It was pointed out that the study may raise a number of questions about general air quality issues in the community unrelated to the Irving Refinery Upgrade. The current assessment will, where possible, provide at least qualitative evaluations of such issues. In the longer-term, such questions can only be resolved through a longer-term comprehensive Public Health Management Study focussing on the Saint John airshed. Nevertheless, it was emphasized that the current study will be able to provide a definite answer on the possible risks of adverse health effects related to the upgraded refinery.

Questions were raised regarding how the report of the current study would be made public. The Study Team stated that it was unclear at this point precisely how the results of the study would be provided to the community. Clearly, the assessment results will be provided to the public. However, public disclosure of certain data would have to be restricted (*i.e.*, personal medical/health records or data related to individual properties) to ensure people's privacy is respected. Concerns arose as to whether Irving would scrutinize the report and if the results could be edited or manipulated. Participants were assured that while the report assumptions could obviously be questioned, the specific scientific findings and data in the report would not be changed.

Questions were raised of possible health impacts from airborne emissions, particularly those leading to cardiorespiratory health problems such as asthma. Points raised during the meeting by the committee members included the following:

- One of the most common health concerns of the community is asthma. There were a number of concerns about the rising rate of 'puffer' usage in the area, particularly by children. The Study Team was told that 1/3 of the students at Simonds Junior High School were using puffers for the treatment of respiratory problems. Because puffers require a prescription, the Study Team indicated it was quite likely that area-specific information on puffer use would be available through the Canada Health system. Indoor air quality in schools was also identified as a concern.

- Concerns about the cancer incidence rate in the area were also expressed. One resident noted that about six people have died from cancer within eight houses of each other, although the specific type of cancers involved was not known. The Study Team ensured those in attendance that this type of information would be collected during the Public Health Assessment of the current study.
- Another participant noted her experience with oil fumes. She experienced muscle problems and fatigue until the oil heating system in her house was removed. A doctor had told another participant that his own sinusitis was due to air pollution.
- The question was raised by one participant whether air pollution could affect a person's oxygen intake while participating in sport activities.
- Concerns were expressed regarding examination of exposures during different seasons of the year and the effects of fog on exposure/toxicity of emissions. The Study Team indicated that this information was very important in the current assessment, and would be included.
- One participant stated that low-sulfur fuel should be required all the time at the major industrial emission sources in Saint John, particularly NB Power.
- Concern was expressed about possible impacts of emissions from refinery on plants and vegetation in the area, and the difficulty experienced in growing plants and trees.
- Concerns were expressed about the oily smell, particularly in the Grandview Avenue area. The Study Team noted the issue of odour for inclusion in the assessment.
- Questions were asked whether the proposed pollution control/prevention equipment will be sufficient to cut down dangerous emissions to ensure public health safety. Team Members noted that this will be the major focus of the current assessment.
- One committee member indicated that collecting samples of water in Little River downstream of the refinery, before and after the upgrade would be useful.
- A number of exposure pathways were identified in the community including:
    - Snow – Emissions occur in the winter and children eat the snow.
    - Fishing – Fishing camps at Beaver Lake and Ladamore Lake. Community participants indicated that Environment Canada would have information on any sensitive lakes in the area.
    - Hunting – Recreational hunting, specifically moose and deer, occurs in the surrounding area.

- The Study Team noted that, at the request of the community, these possible exposure pathways will be included in the current assessment where data are available.

A-2.5 Summary of Public Comments and Concerns from the Public "Drop-In" Session

Approximately 20 individuals from the community visited the two-hour 'drop-in' session held at the Forest Hills Elementary School on Thursday, May 27, 1999. Study Team members in attendance were Dr. Bob Willes and Lisa Marshall of CANTOX ENVIRONMENTAL INC., Becky Steffens with Health Risk Management Group, as well as Gerry Hill and Christene Matthews-Celeste from the Northcote Group. John Dicaire and Neil Thomas represented both the Department of Health and the Project Working Group. Judy LeBlanc and Sandra Thibodeau also participated as community representatives on the Project Working Group. Local news media organizations present included: Global Television, Saint John Evening Times-Globe and CFBC.

The purpose of the 'public drop-in session' was to provide local residents with an opportunity to learn more about the Public Health Risk Assessment, speak individually with the Study Team about their questions or concerns regarding the public health aspects of the IOL Refinery 'Upgrade', and provide specific input into the Assessment at an early stage in the process.

In addition to printed background information sheets describing the Public Health Risk Assessment process, the Study Team also used an 'in-focus' projector system and a standing display unit to assist in conveying the essential elements of the project to session participants. Background information sheets provided to all visitors on the Assessment also provided details on the Project's 'Community Response Line' telephone service (642-8957). A copy of the background information is provided in Section A-3.

Comment sheets were also made available to participants for providing any written responses, questions or concerns as well as their phone number, if they wished to be contacted for further individual discussion. Participants had the option of submitting these comment sheets during the May 27 'drop-in', or forwarding them to the project mailing address at a later time. The comment sheet also provided a local mailing address where written comments or questions from the public could be forwarded at any time during the study period. This address is: Public Health Risk Assessment - IOL Refinery Upgrade, CANTOX ENVIRONMENTAL INC., P.O. Box 531, Saint John NB, E2L 3Z8. The 'comment sheets' also provided an opportunity for members of the public to add their addresses to a mailing list which will be used throughout the study period for distributing update information on the Assessment to local stakeholder groups and interested members of the public. All participants who completed these sheets during the 'drop-in' session confirmed their interest in receiving update information as the project proceeds, as well as a final summary of the technical assessment results, upon completion of the project.

Specific questions/issues raised during the meeting by the participants included the following:

- Several visitors to the session wanted to know why the Refinery is putting its new waterline close to the existing boundaries of Creighton Avenue properties.

- Noise pollution during and following construction was an expressed concern of several individuals, particularly with the removal of the tree buffer on Creighton Avenue and Grandview Avenue. Some residents also fear with the new units that noise during refinery operations will increase substantially.

- The potential for well contamination was a concern for one resident living in the Red Head area.

- One individual stated that although SO_2 emissions are predicted to decrease, 'does that allow for an increase in other particulate emissions?'

- One individual felt that 'more air monitoring equipment is needed and more pollutants require monitoring'.

- Concerns regarding odour, particularly an oily gas and sulfur smell, were expressed.

- Concern was also expressed about the incidence of cancer, respiratory illnesses and asthma in the area.

- One resident took the opportunity to express her cynicism about the Refinery and the overall study itself. In this connection, the issue of who is actually paying for the study was also raised.

- Property damage from high acid levels in local outdoor air was also identified as a concern.

- 'More public information is needed on the construction of the Refinery 'Upgrade', its processes, and the amount of reduction in air emissions expected.

- In response to a question from the Study Team, one resident noted that he consumes a significant portion of his vegetable intake from his garden.

Detailed information on the activities of the community was collected at the public drop-in session (*e.g.*, amount of time spent inside and outside; amount of home grown vegetable garden produce). This information was included in the exposure assessment. In addition, community members identified several specific chemicals which were of potential concern. These chemicals were included in the assessment.

A-3.0 BACKGROUND INFORMATION DOCUMENT

Background information on the PHRA was prepared in an easy to read format and distributed to various individuals / groups throughout the assessment. A copy of this document is provided below.

Public Health Risk Assessment of the Irving Oil Refinery Upgrade Background Information

The Department of Health and Community Services has commissioned a Public Health Risk Assessment of the Irving Oil Refinery Upgrade. This assessment is one of the conditions of approval to be met by Irving Oil Ltd. before an operating permit will be issued by the Department of Environment for the upgrade component of the refinery. The study will be funded by the Department of Health and Community Services and recovered from Irving Oil. The assessment will take five months to complete. Public input into the assessment is essential in order that it thoroughly reflects and addresses the community's needs and concerns related to the upgrade.

The maritime office of CANTOX ENVIRONMENTAL INC. has been selected to conduct the Public Health Risk Assessment. CANTOX ENVIRONMENTAL INC. are experts in the field of risk assessment and will be assisted by Health Risk Management Group Inc. (HRMG), experts in public health assessment. Mr. Gerry Hill, a public consultation specialist, will assist the technical team of CANTOX ENVIRONMENTAL INC. and HRMG.

What is a Public Health Risk Assessment?

A Public Health Risk Assessment is a scientific study of the possible risks of adverse health effects from specific emissions. These potential risks are put into perspective by evaluating the public health status of the community potentially affected by the emissions.

The Public Health Risk Assessment of the Irving Oil Refinery Upgrade will consist of two main components: a *risk assessment* component and a *health assessment* component. The *risk assessment* component determines whether the amounts of emissions from the upgraded Irving Oil Refinery (separate from other sources of emissions that occur in the community) could potentially cause health problems in people living in the surrounding communities now or in the future. The *health assessment* component uses hospital and medical records, along with interview techniques to assess the actual health status of people in the community. The combination of the information from the health risk assessment and the community health assessment will enable an evaluation of the possible significance of emissions related to the upgrade to the health of people living in the community.

How Will the Community be Involved in the Assessment?

Input from the community is important so that the Public Health Risk Assessment addresses the health issues of concern related to the refinery upgrade to people living in the community. There will be a variety of ways that the community can provide comments and obtain information on the assessment including the following:

- CANTOX ENVIRONMENTAL INC. / HRMG will initiate individual discussions / meetings with identified community stakeholders / stakeholder groups to identify the issues of concern.
- Public drop-in sessions will take place in the community for anyone who wishes to attend. At this time, individuals will have the opportunity to learn more about the assessment, to communicate their concerns about the upgrade to the study team, as well as provide their input into the assessment.
- Newsletters will be distributed during the time frame of the assessment to keep individuals updated on the progress of the project.
- A local telephone line has been set up for individuals to leave their questions and / or provide input on the assessment. The number for the response line is 642-8957.
- Information about the project will be posted on several websites including the CANTOX ENVIRONMENTAL INC. website (www.cantoxenvironmental.com).

How Will the Public Health Risk Assessment be Conducted?

The Public Health Risk Assessment will be conducted using procedures developed by regulatory agencies such as Health Canada, ATSDR (Agency for Toxic Substances and Disease Registry) and the Canadian Council of Ministers of the Environment. The assessment is divided into two components, the *risk assessment* component and the *health assessment* component. Specific steps of the risk assessment and health assessment components of the study include:

Risk Assessment Component

- *Problem Formulation Step*: During this step, information will be gathered and evaluated related to site layout; emissions which may be of potential concern; possible "routes" or "exposure pathways" by which residents may be exposed to these emissions; the lifestyles of people within the area which provide the highest potential for exposure and other specific concerns raised by the community.

- *Hazard / Toxicity Assessment Step*: Exposure limits for many chemicals have been established by agencies such as Health Canada, the U.S. Environmental Protection Agency and the World Health Organization. An exposure limit represents the largest exposure that could occur without causing concern for possible adverse health problems. **Exposure limits** are established following a detailed review of the specific toxicology data for a chemical by teams of scientists. Where available, regulatory exposure limits will be used in this assessment. If no regulatory limit is available for a chemical, then an exposure limit will be developed using the same procedures as those of the regulatory agencies.

- *Exposure Assessment Step*: In this step, exposures to emissions from the upgraded Irving Oil Refinery will be estimated using mathematical models. This will determine the level of each of the chemicals from the upgraded units which residents could possibly be exposed.

Background ambient concentrations will also be evaluated to assess exposures of people to total sources of emissions, including those not related to the Irving Oil Refinery. These other sources of emissions include those arising from human activities, other industry, and background or "natural" sources. Information obtained from the community will be factored into these mathematical models to ensure the exposures calculated are relevant to the various factors identified by the community.

- *Risk Characterization Step*: This step determines whether or not the estimated exposure of sensitive people to emissions associated with the Irving Oil Refinery upgrade would be expected to result in any adverse health problem/benefit. To do this, the estimated exposure levels (from the exposure assessment step) are compared to the exposure limits (from the hazard / toxicity assessment step). This comparison is called an **Exposure Ratio.**

Health Assessment Component

- *Identification of Risks and Health Concerns*: Along with the public consultation program, this step will enable the identification of public health-based questions and community concerns stemming from the construction and proposed changes to the facility. After speaking with the community and all interested parties, data will be located that details community health and risk factor information. The sources of data may be scientific studies specific to the community, hospital admission/discharge rates for the community, disease registries, *etc*.

- *Predicted Change in Health Impact*: This step involves a detailed assessment of the current health status of the Saint John community prior to the proposed Irving Oil Refinery upgrade by reviewing the data sources identified in the first step. For example, this information could contain incidence rates and frequencies of hospital admissions and discharges for respiratory illnesses, emergency room visits, *etc*. Utilizing the results of the risk assessment and these data sources, statistical analyses will be conducted in order to predict the impact of the proposed upgrade on the community.

For more information or to provide input into the assessment, please contact:

Telephone Information Line: 642-8957

A-4.0 SUMMARY OF INFORMATION OBTAINED *VIA* THE COMMUNITY RESPONSE TELEPHONE LINE, WEB SITE ADDRESS, E-MAIL OR THE LOCAL POST OFFICE BOX

Community Response Telephone Line

The PHRA Community Response Line (642-8957) began operating 24 hours a day, seven days a week in Saint John on May 25th. For the following 18 weeks until September 30, it was monitored at least once a day by the Northcote Group. Most callers to the line provided their names and telephone numbers and asked for a return call. The Northcote Group typically made the first contact to provide basic information about the project, obtain more detail on the individual question or concern, and ask whether the caller wished to discuss it more fully with a scientific member of the study team. In the majority of cases, callers requested such a return call, and the subsequent discussion took place within 24 hours of the initial message being received.

Input Received

Over the 18 weeks, relatively few calls were received on the Community Response Line asking for information on the PHRA. Apart from requests for administrative information (project schedule, website location, e-mail addresses, phone numbers, *etc.*), a total of 29 calls from 16 individuals were received during this period.

In the first six weeks following the 'public drop-in' in late May, two callers asked about the scope of the PHRA study, with respect to other sources of industrial air emissions in East Saint John and, in particular, the Courtenay Bay generating station. Another caller expressed concern about the variety of cancer-causing chemicals used and/or generated at the refinery and asked if they would be looked at as part of the PHRA study. The same caller indicated concern about noise levels after the refinery upgrade was complete, and the need to consider different seasons of the year, as well as the impact of fog.

A separate request was received for information on how the concept of public health risk assessment could be applied to a former industrial site on the outskirts of Saint John, where groundwater contamination has been a concern for some years.

One caller asked for help in interpreting some of the mathematical equation symbols used in a background document, which had been provided by the study team following a request at the 'stakeholder' meetings in late May. The question of whether the final PHRA report would be subject to "peer review" was raised in another call, while a local resident concerned about water quality in East Saint John requested clarification on whether the PHRA would involve sampling and data analysis on surface water from Little River.

Another caller expressed concern about 'fugitive emissions' from tank cars at the upgraded refinery's 'disembarking area', as well as the 'new technology' to be employed at the facility, and whether it had been proven to be safe in previous situations. The need for adequate safety training for those employees who would be operating such systems in the future was strongly recommended.

During its initial weeks of operation, occasional calls were also received on the Response Line from local residents reporting a specific odour in their immediate area, together with the time and location where it had been first noticed. In each of these instances, the information received was noted and relayed as soon as possible to the Saint John office of the Department of the Environment. In cases where such callers also left their telephone number on the line, a return call was made to summarize the goal of the PHRA study and suggest, if possible, that such information be reported directly to the local NBDOE office.

In late June and early July, several calls were received from residents in the community expressing concern about issues related to construction operations at the refinery upgrade site. The 'mental health impacts' of such activity very close to local residences were reported as a serious concern. These included the noise of pile-driving and hours of operation at the construction site, as well as removal of trees immediately behind homes on Creighton Avenue, in connection with installation of a water pipeline on refinery-owned property in the area.

A resident of the Red Head area phoned to express personal concern about the long-term health impacts of living 'downwind' from the existing refinery, while a resident from Champlain Heights asked about obtaining sampling data on home garden plants/produce to determine whether refinery emissions were impacting them. In another call, concern was expressed about alterations made by the NB Government, in early June, to the Certificate of Approval covering Irving Oil Ltd. construction activities at the site.

Between mid-July and early August, no calls were received at the Response Line asking questions and/or providing comments about the PHRA study. During this period, a physician in the community sent a brief written response to the study team which stated that "indoor air quality" was "most important for respiratory disease". In a subsequent telephone call with the doctor, the importance of 'indoor air quality' as a prime causative factor in the incidence of asthma was further underlined.

Distribution of the mid-project newsletter in the community took place during the first week of August, and included 3130 copies delivered by Canada Post to residential addresses in East Saint John. A copy of the newsletter is provided in Section A-5.0. Calls received in the week following newsletter distribution included two reports that 'oil smells' in the air around Champlain Heights seemed stronger since construction had started at the refinery, in comparison to previous years. One caller expressed the opinion that the community's air quality monitoring system is inadequate, because no monitors are presently operating in the Red Head area. The air quality impact of the Courtenay Bay Generating Station in East Saint John was raised by another caller, in relation to an incident involving 'fall-out' from the power plant.

In mid-August, the issue of future 'upset conditions' and possible major accidents at the refinery were raised in several calls to the Response Line. Serious concern was expressed that the terms of reference for the PHRA study did not include a requirement to examine such questions in detail. Specific issues raised ranged from possible process problems and/or upsets during start-up or maintenance periods, to the potential for major explosions and fires at the facility caused by catastrophic events such as earthquakes.

One caller also expressed concern about the future air quality impact of 'flaring' at the upgraded facility, with respect to the frequency of such events; the emissions which might be caused by such 'flaring', and their public health impact in the local airshed. Particulate emissions were specifically identified by the caller as a major concern requiring detailed examination. Concerns about 'fugitive' VOC emissions during the filling or emptying of tank cars at the disembarking area for the new facility were voiced in another call, together with criticism of the changes and additions made by the Province in early June to the Company's Certificate of Approval to Construct.

Between mid-August and September 30th, eight calls were received on the Community Response Line. A Champlain Heights resident registered concern about a three-month extension in the pile-driving schedule at the construction site, beyond the end of August, and the resulting noise impacts involved. A Red Head area resident pointed to refinery emissions over the past five years, and reported a variety of personal health-related impacts. A proposal to develop a 'laydown area' for pipe during construction, which would require temporary re-zoning of land near Champlain Drive, was raised by a caller in connection with increased noise, dust and vehicle emissions, as well as psycho-social impacts for residents in the area. Another question focussed on public safety risks (the potential for fires and explosions) in connection with the expanded use of natural gas at the Courtenay Bay (Bayside) power station, and its proximity to the refinery site. Heavy traffic volumes on Champlain Drive related to project construction were also raised by the caller, together with insufficient public safety barriers/fencing at the site of ongoing work near the Silver Falls gorge.

A national newspaper article on September 6th prompted another call to the Response Line, referring to reports that production volumes at the upgraded refinery would increase by 50,000 barrels a day, and that the completed project would represent commencement of petro-chemical production at the facility. The caller expressed serious concern regarding these statements in the media, which appeared to conflict with the descriptive information provided to government and the public to date about the nature of the project.

In mid-September, a caller phoned to voice health-related concerns about air quality in the East Saint John area during periods of poor weather for dispersion of pollutants. Another resident, who was concerned about the impact of particulate emissions, noted that some air quality standards for Saint John are more stringent than elsewhere in New Brunswick. The caller felt that tougher regionally-specific standards should be applied to the present health risk assessment process. This caller also expressed concern about potential impacts on local vegetation and wildlife following the refinery upgrade and felt potential ecological risks should be evaluated. In addition, the caller felt a peer review of the PHRA would be important in addition to the evaluation of upset conditions.

The final call received on the Community Response Line during the period concluding on September 30 was from an area resident asking for detailed information about the specific modelling system employed by the study team during the risk assessment process.

A brief written submission was also received at the study team's Saint John postal address during September. It came from a local resident who called for expanded air quality monitoring systems in the Red Head area, as well as on all emission stacks. The writer also strongly recommended switching to natural gas at both the Courtenay Bay and Coleson Cove Generating Stations; cleaner fuels for automobiles, trains, trucks, *etc.*, as well the use of lighter (less sulphur content) crude oil at the Refinery.

In total, during the 18 week period, two written responses were received at the study team's Saint John postal address. No comments were received from community members *via* the website contact or e-mail address.

Monitoring both the Community Response Line and the local postal address continued after September 30th. A total of six calls were received on the line in October and November, most of which concerned administrative information such as the dates for public release of the PHRA report, final public drop-in, *etc.* In late November, one resident of the community phoned to express concern about noise levels at the construction site. No written input was received at the study team's postal address during October and November.

A-5.0 NEWSLETTER

At the mid-way point of the project schedule, an eight page newsletter was prepared and distributed in the community to provide background information of the PHRA and summarize the initial aspects of the project. A copy of the newsletter is provided below.

PUBLIC HEALTH RISK ASSESSMENT
IRVING OIL REFINERY UPGRADE

COMMUNITY NEWSLETTER
AUGUST, 1999

Assessment Project Underway

The Public Health Risk Assessment of the Irving Oil Refinery Upgrade began its research phase in early May. The study team has been focussing on two key areas thus far, according to Project Manager Lisa Marshall of CANTOX ENVIRONMENTAL INC., a Saint John native.

" In studies like this, we begin by searching out the most comprehensive technical data sources available. We also start public consultation in the early stages of the process," she said- "Learning directly about the surrounding community and the specific concerns of local residents is very important to the study. " Although construction of the upgraded units at the refinery is not included as part of the scope of the public health risk assessment, any construction complaints received by the study team will also be passed on to Irving Oil Limited and the Department of Environment in an expedient manner.

The public health risk assessment of the Irving Oil Refinery Upgrade consists of two main components risk assessment and public health assessment. To ensure each of these components are examined in depth, CANTOX ENVIRONMENTAL INC. of Canada has joined forces with Health Risk Management Group (HRMG) of Washington D.C. for this assessment project. The primary overall objective of the assessment is to identify whether there will be any potential future public health issues related to the new "upgraded" refinery.

COMMUNITY RESPONSE LINE

If you have a question or comment about this public health risk assessment at any time please don't hesitate to contact us. Our community response telephone line can be reached 24 hours a day and

we check for incoming calls on a regular basis including weekends and holidays. The number is:

642-8957

"Project Working Group" includes Community Representation

The Cantox/HRMG Study Team reports directly to the New Brunswick Department of Health and Community Services, which is responsible for overall direction of the Public Health Risk Assessment on the Irving Oil Refinery Upgrade. Earlier this year, the Department formed a project working group to oversee the study process. This group is chaired by John Dicaire, Assistant Deputy Minister of Health, and includes officials from the Department of Health and community Services, the Department of the Environment, Irving Oil Limited and the City of Saint John, as well as two community representatives.

" We recognize the importance of this study to all segments of the Saint John community and see the representative character of the project working group as a distinct advantage." "It's proving very helpful in strengthening communication links between the study team, local stakeholders, Irving Oil Limited and the two provincial agencies involved, " said Mr. Dicaire.

Priority on Public Input

Maintaining effective information flow between the study team and the Saint John community throughout the assessment has been seen as a priority by the project working group since the outset.

Dr. Robert Willes, Vice-President of CANTOX ENVIRONMENTAL INC., notes that such an approach fits well with the way the study team likes to operate. "We've

Public Health Risk Assessment Components

Risk Assessment Component

+

Public Health Component

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Significance of upgraded refinery emissions to community health

conducted hundreds of studies like this over the years, in many different communities, dealing with a wide range of industrial facilities or development projects. Involving local residents from the study area, as well as representative stakeholder groups, has always proven to be a real advantage. There's definitely no substitute for local knowledge," said Dr. Willes, "We always " to capture as much community input as possible at an early stage, when such information can be factored into our study design," he said.

To assist Cantox and HRMG in public consultation programming for this project, the Northcote Group Limited of Fredericton is also part of the study team. Gerry Hill of NGL has worked on a variety of public consultations in Saint John over the years, including development of the New Brunswick 'Clean Air Strategy.'

Stakeholder Discussions/Public "Drop-In"

During the week of May 24th, the study team held a series of !stakeholder consultation meetings in Saint John with a variety of groups and organizations interested *in* the assessment project. These included: the Citizens Coalition for Clean Air, the Saint John **ARMA** Committee, the Irving Oil Community Awareness Liaison · Committee, the Saint John Regional office of the Department of the Environment, as well as the project working group. Study team members in Saint John during the week included Lisa Marshall and Dr. Robert Wiles of CANTOX ENVIRONMENTAL Inc., as well as Becky Steffens and Dr. George Carlo, Chair of HRMG.

In addition to the various stakeholder meetings, a public 'drop-in' session was held at Forest Hill Elementary Shoot on Thursday evening May 27. This provided individual members of the community and the news media chances to ask questions, discuss any aspect of the assessment process, provide input, etc.

Project Manager Lisa Marshall notes that each of the meetings produced valuable discussions and a great deal of useful information was obtained as a result. 'We found all the stakeholder groups very interested in the public health risk assessment process and ready with both detailed questions and valuable input,' she said, "Members of the public who attended the 'drop-in session on May 27 had a range of similar questions and we were very pleased with the chance to talk to people in an informal 'one-on-one' atmosphere. Participants also had the opportunity to register their names and addresses so we could send them updated 'information as the project goes forward."

Project Status

Since the project began. CANTOX ENVIRONMENTAL Inc. has been gathering and reviewing data on the Irving Refinery Upgrade, in addition to local air data, as part of the problem formulation phase of the risk assessment. Through the initial public consultation activities, a number of exposure pathways were identified as being of potential concern to the community (e.g., ingestion of local vegetables, inhalation of various substances associated with "fog"). Searching for information on these potential pathways 15 underway so they can be evaluated in the assessment. Cantox has also begun 'identifying exposure limits for emissions of potential concern and compiling exposure assumption data (e.g., amount of time spent inside and outside, amount of local vegetation consumed, etc.) for the toxicity and exposure assessments, respectively.

From the public drop-in, stakeholder meetings and calls to the community response line, a number of concerns related to the construction phase of the refinery upgrade have been reported. Evaluating potential health risks associated with construction of the upgraded units at the refinery is not included as part of the scope of the public health risk assessment. However, any construction complaints received by the study team will be passed on to Irving Oil Limited and the Department of Environment in an expedient manner.

Health Risk Management Group is in the process of collecting data on the health status of Saint John area residents. These data will include relevant health conditions, geographical location and psycho-social variables identified through discussions with the community and a review of earlier literature. This information will be used in conjunction with the information gathered by CANTOX ENVIRONMENTAL INC. in evaluating any potential public health impact from the Irving Oil Refinery upgrade.

Risk Assessment Component

This public health risk assessment is being conducted by the study team using procedures developed by regulatory agencies such as Health Canada, AT5DR (Agency for Toxic Substances and Disease Registry) and the Canadian Council of Ministers of the Environment, As noted earlier, the project includes two separate, but complementary components - 'risk assessment' and 'health assessment.'
The risk assessment component is divided into four major steps.

1. Problem Formulation

Information is gathered and evaluated relating to site layout; emissions which may be of potential concern; possible 'routes" or "exposure pathways" through which residents may be exposed to these emissions; the lifestyles of people within the area which provide the highest potential for exposure and other specific concerns raised by the community.

2. Hazard/Toxicity Assessment

Exposure limits for emissions of potential concern will be identified. Exposure limits for many chemicals have been established by agencies such as Health Canada, the U.S. Environmental Protection Agency and the World Health Organization. These limits represent the largest exposure that could occur without causing concern for possible adverse health problems, and are established following detailed reviews of toxicology data for the chemicals concerned. Where available, regulatory exposure limits will be used in this assessment.

3. Exposure Assessment

Exposures to emissions associated with the Irving Oil Refinery Upgrade will be estimated using mathematical models that predict the dispersion of the emissions into the surrounding environment and the potential exposure of people to such emissions through a number of exposure pathways. information obtained from the community will be factored into these mathematical models to ensure the exposures calculated are relevant. This will determine the level of each chemical from the refinery to which residents could possibly be exposed. Background ambient concentrations will also be assessed to examine exposures of people to total emissions, including those not related to the refinery. Such other sources include those arising from human activities, other industry, and background or "natural" sources.

4. Risk Characterization

This final step determines whether or not the estimated exposure of people to emissions associated with the Irving Oil Refinery Upgrade would be expected to result in any adverse health problem or benefit.

To do this, the estimated exposure to emissions (from the exposure assessment step) is compared to the exposure limits (from the hazard/toxicity assessment step). This results in an exposure ratio (estimated exposure ~ exposure limit = exposure ratio)-

Health Assessment Component

In broad terms, a public health risk assessment is a scientific study of the possible risks of adverse health effects from specific emissions. These potential risks are put into perspective by evaluating the public health status of the community potentially affected by the emissions. The health assessment component of this project comprises two major steps,

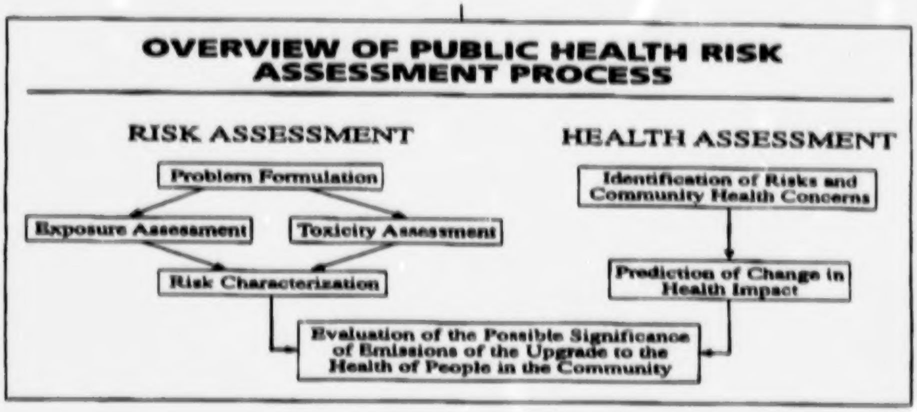
1. Identification of Risks and Health Concerns

Together with the input received through public consultation efforts, this step enables the study team to identify a variety of public health-based questions and community concerns. After speaking with the community and all interested parties, data sources are located which detail community health and risk factor information.

Such information sources may include previous scientific studies specific to the community, local hospital admission/discharge rates, disease registries, etc.

2. Predicted Change in Health Impact

This step involves a detailed assessment of the current health status of the Saint John community prior to the Irving Oil Refinery Upgrade by reviewing the data sources identified in the first step. For example, this information could contain incidence rates and frequencies of hospital admissions and discharges for respiratory illnesses, emergency room visits, etc, This information will be combined with the results of the risk assessment in order to predict the potential impact of the Refinery Upgrade on the health of the community.


OVERVIEW OF PUBLIC HEALTH RISK ASSESSMENT PROCESS
RISK ASSESSMENT
HEALTH ASSESSMENT
Problem Formulation
Exposure Assessment
Toxicity Assessment
Risk Characterization
Identification of Risks and Community Health Concerns
Prediction of Change in Health Impact
Evaluation of the Possible Significance of Emissions of the Upgrade to the Health of People in the Community

BACKGROUND ON CANTOX ENVIRONMENTAL INC.

CANTOX ENVIRONMENTAL INC. is a science-based consulting firm providing expert advice to a wide range of clients on toxicology issues related to human health, the environment and regulatory affairs. The scientific staff of the CANTOX group operate from five offices across Canada and the United States, (Halifax, Nova Scotia; Mississauga, Ontario; Calgary, Alberta; Vancouver, British Columbia and Bridgewater, New Jersey). With more than 50 experienced professionals in areas such as human and aquatic toxicology, environmental fate modelling, human health and environmental risk assessment, as well as risk communication, CANTOX is one of the largest risk assessment firms in Canada.

Over the past decade, the company has conducted several hundred large-scale detailed quantitative risk assessments of potential risks to human health and ecological receptors from exposures to chemicals from a variety of sources. CANTOX scientists regularly contribute to scientific publications and/or conference presentations in the field of toxicology and risk assessment.

The firm also provides expert advice to numerous national and international committees and organizations including the World Health Organization, FEMA, the international Agency for Research on Cancer, the U.S. National Academy of Sciences, the U.S. National Toxicology Program, the Natural Sciences and Engineering Research Council, the Canadian Council of Ministers of the Environment (CCME), the Atlantic Partnership in RBCA implementation (PIRI) Committee and NERAM (Network for Environmental Risk Assessment and Management).

BACKGROUND ON HEALTH RISK MANAGEMENT GROUP

Health Risk Management Group, Inc. (HRMG) specializes in evaluating the public health impact of a given exposure or set of exposure parameters on populations at risk, including residents, workers, and product users. With fifteen years of experience performing public health impact assessments in the United States and the Pacific Rim, company staff have also played a leadership role in developing public health policy in the US over the last decade. Dr. George Carlo, for example, wrote the enabling legislation for the United States Agency for Toxic substances and Disease Registry (ATSDR), the authority responsible for the public health aspects of hazardous waste contamination.

In previous projects, HRMG has studied dioxin, 2,4-D, chlorine, hazardous waste, asbestos, cement kilns, silicone breast implants, cellular telephones, pharmaceuticals, and the administration of the polio vaccine to determine their effects on public health and/or the environment. The company employs the most current scientific knowledge in the areas of public health investigation, communication, legislation, regulation, and litigation, as shown through multiple publications on these matters in peer-reviewed scientific and medical journals. HRMG has a proven track record with U.S. federal regulatory agencies such as the U.S. Environmental Protection Agency, U.S. Food and Drug Administration, Federal Communications Commission, and occupational Safety and Health Administration. Company staff have also served on international advisory panels, including those for the World Health Organization and the International Agency for Research on Cancer.

Saint John Air Monitoring Data

The Cantox/HRMG study team has access to an extensive amount of historical data on ambient air quality readings in Saint John over several years, as compiled by the New Brunswick Department of the Environment with the assistance of Environment Canada, as well as Irving Oil Limited and Irving Pulp and Paper Ltd. Data generated through Irving company monitors is relayed electronically to NSDOE's air quality monitoring computer system. This represents a significant data resource for the assessment process as equivalent data are not always available in communities where such studies are carried out. At the present time, a total of 12 separate air quality monitors operate on a continuous basis in Saint John, as indicated on the map below[2]:

CONTACTING THE STUDY TEAM

If you have a question or comment about this Public Health Risk Assessment at any time, please don't hesitate to contact us. Our Community Response Telephone Line can be reached 24 hours a day and we check for incoming calls on a regular basis, including weekends and holidays. The number is:

642 8957

If you wish to send us a written question or comment at any time, our mailing address is:

Public Health Risk Assessment
Irving Oil Refinery Upgrade
CANTOX ENVIRONMENTAL INC.
RO. Box 531
Saint John, NB E21- 3Z8

Our website is located at: http://www.cantoxenvironmental.com/irving.htm

Our email address is: lmarshall@cantoxenvironmental.com

Watch for our second newsletter which will be available in the early fall.

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[2] Map could not be scanned into document.

APPENDIX B

CONSTRUCTION ISSUES

B-1.0 PUBLIC CONCERN RELATED TO CONSTRUCTION OF THE IOL REFINERY UPGRADE

As stipulated in the Terms of Reference for this Public Health Risk Assessment (PHRA) compiled by the PHRA Working Group, public concerns relating to construction activities for the upgrade project were recorded, summarized and forwarded to representatives of both Irving Oil Refinery Limited and the NB Department of the Environment. It was outside the study scope to specifically address construction issues in the PHRA. A summary of construction concerns, as identified during initial public consultations and through the Community Response Line, is outlined below:

- Residents of Creighton Avenue were concerned about the location of a water pipe line and chain linked fence behind their homes and on Refinery-owned property and the amount of "buffer" between their properties and the construction area. The main issue for the residents was the loss of trees associated with the water line and fence construction.
- Additional concerns related to the construction of the water line behind Creighton Avenue and York Street included:
    - A potential decrease in property values and loss of enjoyment of property as a result of tree-cutting behind their lots with the future erection of a chain-linked fence five metres from their properties and the cutting of trees (which were described as providing a visual buffer between their homes and the refinery).
    - Concern that the current noise and air pollution levels would increase as a result of tree removal behind Creighton Avenue properties.
    - Some callers indicated that their family's mental health was adversely impacted by the water line construction activities. They indicated that this was having psycho-social effects on the community and that residents were distressed and saddened by the cutting of trees, as well as the manner in which it was conducted.
- Several residents (particularly Champlain Drive and Grandview Avenue residents) have complained of noise, as a result of construction activities for the upgrade, particularly pile driving. Some callers indicated that such noise was having mental health and psycho-social impacts on their families. Concern was also expressed that the time frame for the completion of pile driving was extended from August to November.
- A number of residents (particularly Champlain Drive and Grandview Avenue residents) have complained of 'oily smells' coming from the refinery that have been especially strong since construction activities began.
- Concerns have been expressed over heavy traffic volumes as a result of construction on the upgrade. Fumes (especially from diesel vehicles) on Grandview Avenue also have been reported as a concern.

- Concerns were expressed regarding the difference between the list of "additional process units", as identified in the Irving Oil Refinery Limited "Application to Register the Irving Oil Refinery Upgrade Project", and in the "Approval to Construct and Operate " (signed June 10, 1999) (NB DOE, 1999a). Concern was also expressed with the addition of a "disembarking area" to the project which was not mentioned in the application document.
- Concern was expressed over IOL's proposal for a temporary rezoning of land for a laydown area, and over a recent newspaper article indicating IOL would be expanding into the Petrochemical business.

Copies of all correspondence forwarded to Irving Oil Refinery Limited and the NB Department of the Environment regarding construction concerns are presented on the following pages. In addition, correspondence between IOL and the NB DOE related to support facilities also is included.

CANTOX ENVIRONMENTAL

CANTOX ENVIRONMENTAL INC.
5475 Spring Garden Road, Suite 503
Halifax, NS B3J 3T2
Phone: 902 429 0278
Fax: 902 429 0279

June 9, 1999

Mr. Kirk Gordon
Manager, Project Assessment
N.B. Environment
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Dear Kirk:

During the stakeholder meetings and public drop-in session held the week of May 24th, a variety of issues related to construction of the Irving Oil Refinery Upgrade were brought forward. As requested in the Terms of Reference for the Public Health Risk Assessment, I am passing these concerns onto the Department of the Environment and Irving Oil Limited to decide on the appropriate course of action.

Specific construction issues identified during public consultation included:

- Residents of Creighton Avenue were concerned that an Irving Oil Refinery water line is to be located behind their houses (residents are under the impression that the water line will be located 25 feet from their properties, however a local politician indicated to residents that the line will likely be moved to 50 feet from their homes). The main concern the residents have with the pipeline is the loss of trees. The residents feel the trees help to control the noise levels associated with the refinery, provide filtration of pollution and allow them to enjoy their properties (*i.e.,* the trees block the view of the refinery to a certain degree). While some residents indicated they have been told trees will be re-planted, there is a concern about the size of the tress to be re-planted.

- A couple of residents would specifically like to know why Irving Oil is "putting the water line so close to the property line on properties on Creighton Avenue" (*e.g.,* is there some engineered reason why the pipeline needs to be placed 25 or 50 metres from the homes).

- Many residents (in particular Champlain Heights and Grandview Avenue residents) complained of noise during construction activities (*e.g.,* pile driving). They understand that there will be noise associated with construction, but would like to have quiet periods in the evenings, and on weekends/public holidays.

- Some residents (in particular Champlain Heights and Grandview Avenue residents) complained of an oily smell from the refinery. They have found this smell to be particularly strong lately (*i.e.,* during construction activities).

- A few individuals indicated their concern with traffic and diesel fumes from vehicles on Grandview Avenue.

I hope the level of detail provided in this letter is meets your needs at this time. If however, you require additional information or have any questions, please do not hesitate to contact me at (902) 429-0278. Our Telephone Response Line and P.O. Box continue to be monitored on a daily basis. If additional concerns are identified, we will pass them on to Irving Oil and the Department of Environment as quickly as possible.

Yours sincerely,
CANTOX ENVIRONMENTAL INC.

COPY

Lisa Marshall, B.Sc., PBD
Scientist

cc: Michael Hanrahan, Irving Oil Limited.
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members
Susan Atkinson, Environment

CANTOX
ENVIRONMENTAL

CANTOX ENVIRONMENTAL INC.
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June 9, 1999

Mr. Michael Hanrahan
Irving Oil Limited
Refining Division
P.O. Box 1260
Saint John, N.B.
E2L 4H6

Dear Michael:

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Lisa Marshall, B.Sc., PBD
Scientist

cc: Kirk Gordon, Environment
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members

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July 12, 1999

Mr. Kirk Gordon
Manager, Project Assessment
N.B. Environment
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Dear Kirk:

We have received four calls on our telephone response line over the last several days dealing with specific construction concerns. As requested in the Terms of Reference for the Public Health Risk Assessment, I am passing these concerns onto the Department of Environment and Irving Oil Limited to decide on the appropriate course of action.

Specific construction issues identified by community members on the telephone response line included:

- On the July 1, 1999 holiday, pile driving awoke one family at 7:15 am. The caller indicated that one family member had worked late the evening before (until 12:30 am) and was very disturbed by the early morning noise. The resident wished to make a formal complaint of the metal health and psychosocial impact that the construction was having on their family.
- As mentioned previously, Creighton Avenue residents are concerned with the construction of a waterline behind their properties. Specific concerns related to construction activities identified by the callers include:
  - Potential decrease in property values and a loss of enjoyment of property as a result of the cutting of trees behind their property lines and the future erection of a chain linked fence 5 metres from their properties. One callers indicated that the trees provided a visual buffer between their property and the refinery.
  - Concern that noise and pollution levels would increase as a result of the cutting of trees behind their properties.
  - One Creighton Avenue resident indicated that their metal health was affected by the construction activities. The caller indicated that the construction was having psychosocial impacts on the community and that residents were distressed and saddened with the cutting of the trees and the manner in which it was conducted.
- Callers indicated that they would like to specifically know why the Irving Oil pipeline is being placed so close to the residents property lines. One caller indicated they were frustrated that they were originally told there would be a 25 foot buffer (*i.e.*, area where trees would not be cut), however due to the need to erect a chain linked fence 5 metres

from the residents' property line, the buffer zone was decreased.

- One Creighton Avenue resident indicated that residents would like to have specific details of what is going to be done with the disturbed land behind their properties following construction.

- Concern was expressed regarding the difference between the list of "additional process units" identified in the Irving Oil "Application to Register the Irving Oil Refinery Upgrade Project" (page 2) and in the "Approval to Construct and Operate" (Signed June 10, 1999 - NB DOE; page 1). The units not mentioned on page 2 of the application document, but mentioned in the "Approval to Construct and Operate" (page 1) include: Piperack, piping, storage, blending, and dispensing equipment; Cooling tower unit No. 3; Utility Plant No. 2 (Part of Unit 245); and Associated control buildings.

I hope the level of detail provided in this letter is meets your needs at this time. If however, you require additional information or have any questions, please do not hesitate to contact me at (902) 429-0278. Our Telephone Response Line and P.O. Box continue to be monitored on a daily basis. If additional concerns are identified, we will pass them on to the Department of Environment and Irving Oil as quickly as possible.

Yours sincerely,
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Lisa Marshall, B.Sc., PBD
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cc: Michael Hanrahan, Irving Oil Ltd.
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members
Susan Atkinson, Environment

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July 12, 1999

Mr. Michael Hanrahan
Irving Oil Limited
Refining Division
P.O. Box 1260
Saint John, N.B.
E2L 4H6

Dear Michael:

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from the residents' property line, the buffer zone was decreased.

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August 23, 1999

Ms. Louise Stewart
Project Assessment
N.B. Environment
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Dear Louise:

We have received a couple calls on our telephone response line over the last several days dealing with specific construction issues. As requested in the Terms of Reference for the Public Health Risk Assessment, I am passing these onto the Department of Environment and Irving Oil Limited to decide on the appropriate course of action.

Specific construction issues identified by community members on the telephone response line included:

- The concern with the loss of trees in the Champlain Heights / Grandview Avenue area as a result of construction activities was brought up once again by a community member. The individual stated they were concerned with the potential effects this would have on air quality and noise buffering.
- One community member indicated they had been informed pile driving would not end on August 31 as originally anticipated, but that it would continue for an additional three months. The individual was concerned that the continued noise would have mental health impacts on their family. In addition, the individual felt this information should have been provided to the community at an earlier date.
- One community member indicated their concern with the addition of a disembarking area to the project which was not mentioned in the application document.

I hope the level of detail provided in this letter meets your needs at this time. However, if you require additional information or have any questions, please do not hesitate to contact me at (902) 429-0278. Our Telephone Response Line and P.O. Box continue to be monitored on a daily basis. If additional concerns are identified, we will pass them on to the Department of Environment and Irving Oil as quickly as possible.

Yours sincerely,
CANTOX ENVIRONMENTAL INC.

COPY

Lisa Marshall, B.Sc., PBD
Scientist

cc: Michael Hanrahan, Irving Oil Ltd.
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members
Susan Atkinson, Environment

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August 23, 1999

Mr. Michael Hanrahan
Irving Oil Limited
Refining Division
P.O. Box 1260
Saint John, N.B.
E2L 4H6

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Lisa Marshall, B.Sc., PBD
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cc: Louise Stewart, Environment
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members

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September 10, 1999

Ms. Louise Stewart
Project Assessment
N.B. Environment
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Dear Louise:

We have received several calls on our telephone response line over the last several days dealing with specific construction issues. As requested in the Terms of Reference for the Public Health Risk Assessment, I am passing these onto the Department of Environment and Irving Oil Limited to decide on the appropriate course of action.

Specific issues identified by community members on the telephone response line included:

- Concerns over Irving Oil Limited's proposal to the City of Saint John to obtain a temporary permit for a "laydown area" (*i.e.*, a pipe storage area) that will be located behind Champlain Drive. Specific concerns were expressed regarding the presence of trucks and cranes that will be accessing this area, and the resulting increase in diesel emissions and dust generation. In addition, the beeping sound made by heavy equipment backing up is believed to result in increased noise levels near residences (according to one caller, the fence for the laydown area will be only 50 feet from homes). One caller was concerned that this temporary storage area will eventually become a permanent part of the refinery, resulting in a smaller "buffer" between residences and the refinery property. Overall, community members are concerned about the potential psycho-social effects that this "laydown" area will have on adjacent residences.

- While not an issue associated with the construction of the "King of Cats" project, concerns were expressed over the future conversion of the Bayside power facility to natural gas. Specifically, community members are worried about having a natural gas-powered facility in close proximity to an oil refinery. They wish to know whether there would be an increased potential for upsets or accidents and what the impact of such situations would be. Similar concerns were expressed in relation to the refinery's future use of natural gas to fuel refinery processes. One caller indicated their desire for information on the "compatibility" of natural gas-powered facilities and an oil refinery in close proximity, and how this would impact potential accident scenarios.
- Concerns were expressed regarding the construction site for the waterline at the Silver Falls pumping station. Community members feel this site is a hazard as guard rails by a gorge have been removed, and current barricades are felt to be inadequate with respect to

preventing access to the site. The community members feel that there should be warning signs and "proper" barricades put up at this site. The respondents express the view that, at present, the site is believed to be unsafe and a cause of psycho-social effects.

- The community members have expressed increasing concerns about the heavy traffic on Champlain Drive. Much of the traffic increase has been attributed by the community to workers involved with the refinery upgrade. It is feared that traffic volumes will increase further as more workers are hired for the next phases of the upgrade project. Community members claim that this increased traffic volume is causing psycho-social effects, such as increased stress and frustration for residents as they are "hemmed in" at certain times of day, and have to take longer to get to and from work. They are also concerned that this increased traffic volume could result in emergency vehicles being delayed if they are needed in the neighbourhood. Concerns were also expressed about the potential for traffic accidents involving refinery upgrade workers and kids from the local elementary school, especially during the busy lunch hour. Some members indicated their desire for immediate actions which could help in managing the traffic problem.

- While also not a construction-related concern, one caller left a message regarding a recent news article in the National Post. The article mentioned that Irving Oil Limited would be expanding into the petrochemicals business and that production would increase 50 to 60,000 barrels/day. The caller was upset that these items were not mentioned in the Application document, nor had they been mentioned anywhere else to their knowledge. The caller felt that this issue demanded immediate attention. To address this issue, CANTOX ENVIRONMENTAL INC. contacted Irving Oil Limited. In their response, they indicated that although the capacity of some of the new units is greater than that of existing units, the nameplate capacity of the refinery will remain at 250,000 barrels/day.

I hope the level of detail provided in this letter meets your needs at this time. However, if you require additional information or have any questions, please do not hesitate to contact me at (902) 429-0278. Our Telephone Response Line and P.O. Box continue to be monitored on a daily basis. If additional concerns are identified, we will pass them on to the Department of Environment and Irving Oil as quickly as possible.

Yours sincerely,
CANTOX ENVIRONMENTAL INC.

COPY

Lisa Marshall, B.Sc., PBD
Scientist

cc: Michael Hanrahan, Irving Oil Ltd.
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members
Susan Atkinson, Environment

CANTOX
ENVIRONMENTAL

CANTOX ENVIRONMENTAL INC.
5475 Spring Garden Road, Suite 503
Halifax, NS B3J 3T2
Phone: 902 429 0278
Fax: 902 429 0279

September 10, 1999

Mr. Michael Hanrahan
Irving Oil Limited
Refining Division
P.O. Box 1260
Saint John, N.B.
E2L 4H6

Dear Michael:

We have received several calls on our telephone response line over the last several days dealing with specific construction issues. As requested in the Terms of Reference for the Public Health Risk Assessment, I am passing these onto Irving Oil Limited and the Department of Environment to decide on the appropriate course of action.

Specific issues identified by community members on the telephone response line included:

- Concerns over Irving Oil Limited's proposal to the City of Saint John to obtain a temporary permit for a "laydown area" (*i.e.*, a pipe storage area) that will be located behind Champlain Drive. Specific concerns were expressed regarding the presence of trucks and cranes that will be accessing this area, and the resulting increase in diesel emissions and dust generation. In addition, the beeping sound made by heavy equipment backing up is believed to result in increased noise levels near residences (according to one caller, the fence for the laydown area will be only 50 feet from homes). One caller was concerned that this temporary storage area will eventually become a permanent part of the refinery, resulting in a smaller "buffer" between residences and the refinery property. Overall, community members are concerned about the potential psycho-social effects that this "laydown" area will have on adjacent residences.

- While not an issue associated with the construction of the "King of Cats" project, concerns were expressed over the future conversion of the Bayside power facility to natural gas. Specifically, community members are worried about having a natural gas-powered facility in close proximity to an oil refinery. They wish to know whether there would be an increased potential for upsets or accidents and what the impact of such situations would be. Similar concerns were expressed in relation to the refinery's future use of natural gas to fuel refinery processes. One caller indicated their desire for information on the "compatibility" of natural gas-powered facilities and an oil refinery in close proximity, and how this would impact potential accident scenarios.
- Concerns were expressed regarding the construction site for the waterline at the Silver Falls pumping station. Community members feel this site is a hazard as guard rails by a gorge have been removed, and current barricades are felt to be inadequate with respect to preventing access to the site. The community members feel that there should be warning

signs and "proper" barricades put up at this site. The respondents express the view that, at present, the site is believed to be unsafe and a cause of psycho-social effects.

- The community members have expressed increasing concerns about the heavy traffic on Champlain Drive. Much of the traffic increase has been attributed by the community to workers involved with the refinery upgrade. It is feared that traffic volumes will increase further as more workers are hired for the next phases of the upgrade project. Community members claim that this increased traffic volume is causing psycho-social effects, such as increased stress and frustration for residents as they are "hemmed in" at certain times of day, and have to take longer to get to and from work. They are also concerned that this increased traffic volume could result in emergency vehicles being delayed if they are needed in the neighbourhood. Concerns were also expressed about the potential for traffic accidents involving refinery upgrade workers and kids from the local elementary school, especially during the busy lunch hour. Some members indicated their desire for immediate actions which could help in managing the traffic problem.

- While also not a construction-related concern, one caller left a message regarding a recent news article in the National Post. The article mentioned that Irving Oil Limited would be expanding into the petrochemicals business and that production would increase 50 to 60,000 barrels/day. The caller was upset that these items were not mentioned in the Application document, nor had they been mentioned anywhere else to their knowledge. The caller felt that this issue demanded immediate attention. To address this issue, CANTOX ENVIRONMENTAL INC. contacted Irving Oil Limited. In their response, they indicated that although the capacity of some of the new units is greater than that of existing units, the nameplate capacity of the refinery will remain at 250,000 barrels/day.

I hope the level of detail provided in this letter meets your needs at this time. However, if you require additional information or have any questions, please do not hesitate to contact me at (902) 429-0278. Our Telephone Response Line and P.O. Box continue to be monitored on a daily basis. If additional concerns are identified, we will pass them on to Irving Oil and the Department of Environment as quickly as possible.

Yours sincerely,
CANTOX ENVIRONMENTAL INC.

COPY

Lisa Marshall, B.Sc., PBD
Scientist

cc: Louise Stewart, Environment
John Dicaire, Health and Community Services
Public Health Risk Assessment Working Group members

IRVING OIL LIMITED

REFINING DIVISION

P.O. BOX 1260
SAINT JOHN, N.B., CANADA
E2L 4H6
TEL. (506) 632-2000
FAX: (506) 632-4050

ENVIRONMENT
ASSESSMENTS & APPROVALS
BRANCH
AUG 9 1999

FILE
X FILE

August 4, 1999

Mr. Kirk Gordon
Manager, Project Assessment Section
Environment New Brunswick
P.O. Box 6000
Fredericton, New Brunswick
E3B 5H1

Dear Mr. Gordon:

Presented below are responses to the questions posed to us in a letter dated July 10, 1999.

1. **LPG Storage Spheres – please indicate whether "operation" of the spheres during normal and/or emergency situations involves periodic releases of gas to the atmosphere?**

   Operation of the spheres during normal situations does not involve periodic releases of gas to the atmosphere. During emergency situations, gases passed by PSVs on the spheres, lines, and pumps would be vented to atmosphere.

2. **Rail Car Loading Facility – same as #1 for "operation" of this facility. Also provide information on planned schedules for delivery of empty cars, their loading and subsequent off-site movement. Please identify the responsible party (IOL or rail employees) in terms of maintaining, operating and dealing with upset conditions.**

   Normal operation of the Rail Car Loading facility does not involve periodic release of vapour. Vapour from the cars is returned to the spheres in a closed loading system. When hoses are uncoupled, there may be a minimal release to atmosphere. During emergency situations, gases passed by PSVs would be vented to atmosphere.

   Irving Oil is responsible for filling the cars and dealing with an upset condition when the cars are at the Irving Oil Refinery. Once the cars are loaded, custody of the cars is passed over to CN Rail personnel for transportation to Irving Oil's commercial customers. CN is responsible for maintaining the cars.

   The Irving group of companies maintains Atlantic Emergency Response Team (ALERT) that could assist in the event of an emergency.

3. **Butaner (sp) – what are the anticipated emissions, if any?**

There are no new anticipated emissions from the Butamer.

4. **Heat Recovery Steam Generators please provide details on capacities of boilers #2 and #4 and the HRSG units replacing them (gigajoules/hr or million Btu/hr.)**

For each HRSG's, please provide details on anticipated emissions (concentrations and mass emissions) of sulphur dioxide, particulate matter, oxides of nitrogen, carbon monoxide, carbon dioxide and total hydrocarbons, at full load.

Will the new units displace any steam presently being supplied by boilers 1, 3, 5 & 6, and consequently result in emission reductions for sulphur dioxide, particulate matter, and oxides of nitrogen?

Please indicate whether the use of waste heat from the RFCCU would have an effect on the original need/plan to install a turbo expander?

Please provide a simplified process flow sheet for the operation of the HRSG's and the remaining boilers.

The #2 and #4 boiler firing rate are 337 MMBTU/hr(LHV) and the HRSG units that replace them are 383 MMBTU/hr (LHV). Each replacement boiler will burn refinery fual gas or natural gas.

The anticipated emissions for a refinery gas firing operation for each HRSG are:

NO_x	*76lb/hr*
CO	*34lb/hr*
Total HC	*20lb/hr*
PM_{10}	*4lb/hr*
SO_2	*<1lb/hr*

All numbers are estimates based on vendor provided data.

The new boilers will not displace steam presently being supplied by boilers 1, 3, 5 and 6. The new boilers replace boilers #2 and #4, permitted (I-1368) but not in service.

The replacement of boilers #2 and #4 is independent of the need/plan to install a turbo expander.

5. **Diesel De-waxer – do you anticipate any emissions from this unit?**

Please provide a simplified process flow sheet related to the operation of this unit.

There are no new emissions from this process.

6. **Number 3, Cooling Tower – please describe any chemical conditioners associated with water vapour releases from this unit (type and concentration).**

   Chemical conditioners are not released to atmosphere. This is one of the important features of the conditioning agents we use.

   On May 4th, we received the BetzDearborn Return on Environment Partnership Award. This global award was based, in part, on our selection of environmentally responsible cooling tower conditioners.

I have attached a simplified process sketch of the Dewax Process and a simplified process flow of the operation of the HRSGs and the remaining boilers.

Please call Michael Hanrahan or myself, if you require additional information

Yours sincerely,
Irving Oil Limited
Refining Division

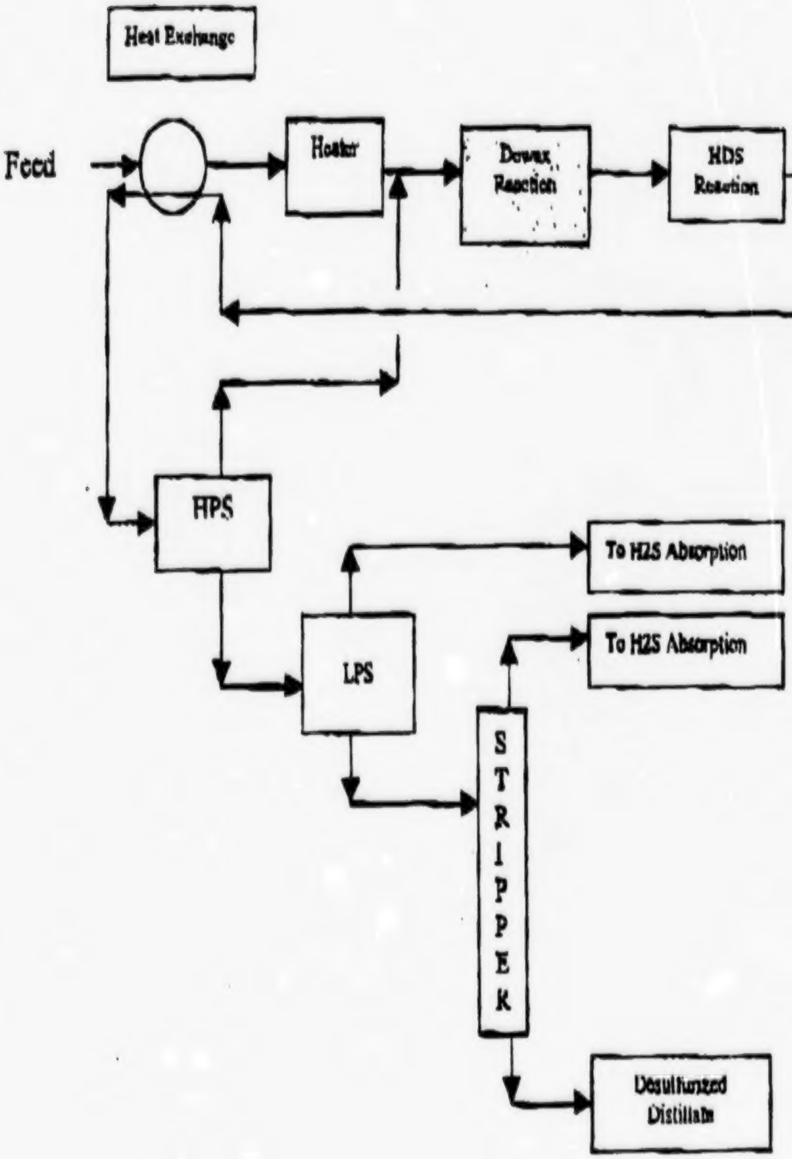
for Gary S. Bischof
Start-up Manager

cc. Michael Hanrahan, Irving Oil

Attachments (2)

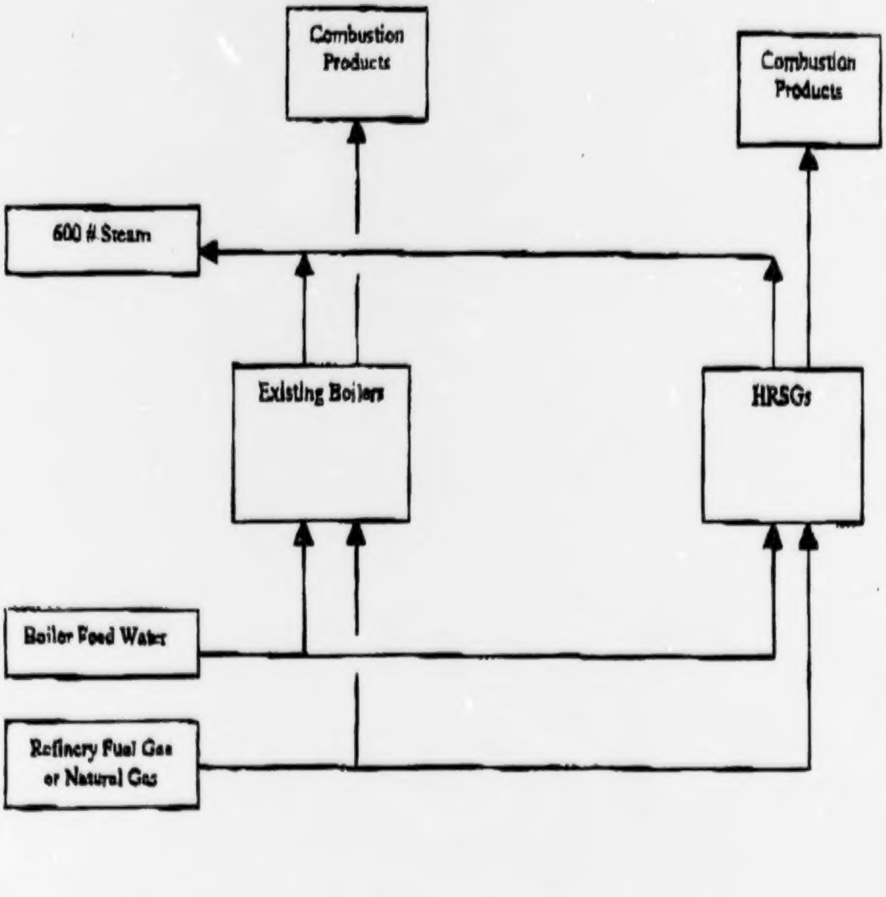
August 4, 1999

Simplified Process Sketch of the Dewax Processs


Heat Exchange
Feed
Heater
Dewax Reaction
HDS Reaction
HPS
LPS
To H2S Absorption
To H2S Absorption
STRIPPEK
Desulfurized Distillate

August 4, 1999

SIMPLIFIED PROCESS FLOW OF THE OPERATION OF THE HRSGs A THE REMAINING BOILERS


Combustion Products
Combustion Products
600 # Steam
Existing Boilers
HRSGs
Boiler Feed Water
Refinery Fuel Gas or Natural Gas

IRVING OIL REFINERY UPGRADE PROJECT

Support Facilities

1. Liquefied Petroleum Gas (LPG) Storage Spheres – construction of two, 25,000 barrel spheres approximately 65 feet in diameter. To be located next to the existing 6 spheres.
2. Rail Car Loading Facility – located in the southern end of the Refinery property, just north of the Irving Paper Mill, will be a rail spur off the existing line and loading racks to accommodate as many as eight rail cars loading LPG.
3. Butamer – a new vessel installed in the #1 Isomerization Unit to convert normal butane to iso-butane. No heater.
4. Heat Recovery Steam Generators (HRSG) – to replaced boilers number 2 and 4, two steam generators that will take waste heat from the Residue Fluid Catalytic Cracking Unit (RFCCU) and convert it into high pressure steam. The HRSGs will burn natural gas or sweet refinery fuel gas only.
5. Diesel De-waxer – a new reactor on the Hydro-desulphurization Unit. No heater.
6. #3 Cooling Tower – instead of extending #2 Cooling tower, a new one will be constructed between the Hydrocracker and the Waste Water Treatment Unit.

FAXED Jul 15/99

#1

New
Nouveau Brunswick

4561-3-620

July 10, 1999

Mr. Michael Hanrahan
Irving Oil Ltd.
Environmental Affairs
Irving Oil Limited
PO Box 1260
Saint John, NB E2L 4H6

Dear Mr. Hanrahan:

Re: Irving Oil Refinery Upgrade Project – Support Facilities

Further to our recent discussions concerning the above, staff from Industrial Approvals and Project Assessment have reviewed the information related to "support facilities" that you provided. As requested, this review was conducted to provide Irving Oil Limited with specific information regarding the department's intentions in addressing each element within the project's regulatory framework. In a number of instances, additional clarification is requested for this purpose. However, for all of the components listed in your submission, each will be managed within the ongoing Certificate of Approval process.

Please consider the following:

1. **LPG Storage Spheres** – please indicate whether "operation" of the spheres during normal and/or emergency situations involves periodic releases of gas to the atmosphere?

2. **Rail Car Loading Facility** – same as #1 for "operation" of this facility. Also provide information on planned schedules for delivery of empty cars, their loading and subsequent off-site movement. Please identify the responsible party (IOL or rail employees) in terms of maintaining, operating and dealing with upset conditions.

3. **Butaner** – what are the anticipated emissions, if any?

4. **Heat Recovery Steam Generators** – please provide details on capacities of boilers #2 and 4, and the HRSG units replacing them (gigajoules/hr or million Btu/hr.)

…/2

P.O. Box 6000
Fredericton
New Brunswick
Canada E3B 5H1

Case postale 6000
Fredericton
Nouveau-Brunswick
Canada E3B 5H1

For each of the HRSG's, please provide details on anticipated emissions (concentrations and mass emissions) of sulphur dioxide, particulate matter, oxides of nitrogen, carbon monoxide, carbon dioxide and total hydrocarbons, at full load.

Will the new units displace any steam presently being supplied by boilers 1, 3, 5 & 6, and consequently result in emission reductions for sulphur dioxide, particulate matter, and oxides of nitrogen?

Please indicate whether the use of waste heat from the RFCCU would have an effect on the original need/plan to install a turbo expander?

Please provide a simplified process flow sheet for the operation of the HRSG's and the remaining boilers.

5. Diesel De-waxer – do you anticipate any emissions from this unit?

   Please provide a simplified process flow sheet related to the operation of this unit.

6. Number 3, Cooling Tower – please describe any chemical conditioners associated with water vapour releases from this unit (type and concentration).

Please contact me should you require any additional information.

Yours truly,

Kirk Gordon
Manager
Project Assessment Section

KMG/cbk

cc: C. Heathwood
D. Grass
S. Atkinson
L. Marshall, CANTOX
Health Risk Assessment Committee

APPENDIX C

LIST OF DATA AND INFORMATION SOURCES REVIEWED AND / OR CONTACTED FOR THE RISK ASSESSMENT COMPONENT OF THE PUBLIC HEALTH RISK ASSESSMENT

C-1.0 LIST OF DATA AND INFORMATION SOURCES REVIEWED AND / OR CONTACTED FOR THE RISK ASSESSMENT COMPONENT OF THE PHRA

The reports, data, peer-reviewed literature, reference materials, online data sources, and personnel which were reviewed or contacted, and considered in the risk assessment component of the PHRA included the following. Additional references considered in the PHRA are provided in the reference sections of the main PHRA report and appendices.

- APCD. 1971. Air Pollution Study in Saint John, N. B. APCD 71-17. Air Pollution Control Directorate Department of the Environment. Bumbaco, M. J., Ritchie, S. A. H., de Koning, H. W.

- ARMA Committee. 1996. Report of the Saint John-Fundy ARMA Committee. Air Resource Management Areas.

- ATSDR. 1998. ATSDR Public Health Assessment Guidance Manual.

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- Bell, Jane. 1984. The Effect of Sulphur Dioxide on Outpatient Department Visits Due to Breathing Difficulty - 1983. Environmental Conservation Project.

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- Environment Canada. 1991. Saint John, New Brunswick Inventory of Nitrogen Oxides and Volatile Organic Compounds Emissions Study Contract # KW203-9-1999. Prepared by P. Lane and Associates Limited.

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- Health Canada. 1995. Investigating Human Exposure to Contaminants in the Environment: A Community Handbook. Cat. No. H49-96/2-1995E. ISBN-0-662-23544-4.

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- Irving Oil Limited Certificate of Approval, 1998. New Brunswick Certificate of Approval. New Brunswick Air Quality Regulation. Certificate No.: I-1368 Class: 1. to Operate Irving Oil Limited - Refining Division, Schedule A.

- Irving Oil Limited, 1999. Information Package provided by IOL to Dr. Nabil Elhadi. January 21, 1999.

- Irving Oil Limited. 1999. Fugitive data for the Irving Oil Refinery 1993 to 1998.

- Irving Oil Limited. 1999. Stack data for O_2, CO_2, THC, SO_2, Particulates, NO_x and CO. Updated in January 1999.

- Irving Oil Limited. 1999. Data on IOL fugitive emissions program.

- Irving Oil Ltd. 1998. Application to register the Irving Oil Refinery Upgrade Project.
- Knight, J. F. L. 1981. The East Saint John, N.B. Dispersion Study 22 July to 5 August, 1981. Environment New Brunswick.
- McCarty, L.S. 1996. A Review of Air Quality in Saint John, New Brunswick. Prepared by L.S. McCarty Scientific Research & Consulting.
- Murphy, M.C., Marquis, D.L., Knight, J.F.L. 1996. Odours in an industrial-residential area near a large oil refinery in East Saint John, New Brunswick - assessment and resolution. New Brunswick Department of the Environment. 13 p.
- NB Environment. 1999. New Brunswick Approval to Construct and Operate I-2133. Irving Oil Limited for the Construction and Operation of the Refining Division Refinery Upgrade. Schedule A.
- New Brunswick Department of the Environment. 1998. An Environmental Monitoring Report of the June 9, 1998 Fire at the Irving Oil Refinery Saint John, New Brunswick.
- New Brunswick Department of the Environment. 1999. A Report on Air Quality Monitoring Results in New Brunswick. Technical Report T-9901.
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- NPRI Web Site. 1999. www.npri-inrp.com and NPRI 1996 Online Searchable Database. URL: http://yvrwww1.pyr.ec.gc.ca/ep/npri/index.html. National Pollutant Release Inventory.
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- Parkhill, Janet C. 1983. The Impact of Local Industrial Emissions on Ambient Sulphur Dioxide Levels in East Saint John - Case Studies. Environment New Brunswick.
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- U.S. Toxics Release Inventory (TRI). 1999. Website. URL: htt7. Prepared bp://www.epa.gov/opptintr/tri/. Including Chapter 7 of TRI Data. Toxics Release Inventory Data for Petroleum Refining (SIC Code 29).
- Weaver, N. 1988. Occupational Medicine. The Petroleum Industry. State of the Art Reviews. Vol 3 (3)371-586
- The Canadian Council of Ministers of the Environment (CCME) web pages on Canada Wide Standards status and overview. URL: http://www.mbnet.mb.ca/ccme/3e_priorities/3ea_harmonization/3ea2_cws/3ea2.html.
- State and Territorial Air Pollution Program Administrators (STAPPA) and Association of Local Air Pollution Control Officials (ALAPCO) webpages. URL: http://www.4cleanair.org/.
- Numerous Refining, Petrochemical and Chemical WWW Sites. Information was divided into information sources and international refining, petrochemical and chemical companies. Over 40 informational sources and 130 international companies were searched. http://www.processassociates.com/sites/links.htm
- Great Lakes Air Toxics Emissions Inventory database.
- Environment Canada Green Lane website. Detailed keyword searches were conducted. http://www.ec.gc.ca/.
- Monitoring Manual and Calculation Procedures For Petroleum Industry Facilities. Http://wwwapi.org/ehs/rh/342-343.htm
- Atmospheric Emissions Inventory Guidebook Chapters. Http://www.eea.eu.int/frdocu.htm
- Production Processes. Http://www.eea.eu.int/frdocu.htm

- Processing Fluid Catalytic Cracking. Http://www.eea.eu.int/aegb/cap04/b410.htm

- Sunoco refinery of Suncor. Http://www.suncor.ca/01about/01fenv4.html#contents

- Mobil Oil Refinery. Http://www.mobil.com/cgi-bin/bld_frameset.cgi? CONTENT-/ehs report/text02.html

- Numerous general online searches were also conducted using a variety of search engines and a range of keywords related to refineries and air emissions data.

- The online compendium of Nova Scotia libraries (NOVANET) was also searched using a range of keywords related to refineries and air emissions.

- A formal literature search was conducted using DIALOG, an online searching system for published journal articles, reports, books that are indexed in over 25 commercial online databases.

- A number of reference sources related to petroleum refining processes and engineering were also reviewed. These included:

    - Petroleum Engineering Handbook
    - Encyclopedia of Chemical Processing and Design
    - Encyclopedia of environmental science and engineering
    - McGraw Hill Encyclopedia of science and technology
    - Perry's Chemical Engineer's Handbook
    - Kirk-Othmer Encyclopedia of chemical technology

- Several Public Health Assessments on oil refineries or former refinery sites prepared by the Agency for Toxic Substances and Disease Registry (ATSDR) were reviewed.

- In addition to the above listed references and sources of information, information supplied to the study team by community members was also reviewed (*e.g.*, newspaper clippings, reports, brochures, *etc.*)

Personal Correspondences

- Charlotte Hawkins of the Texas Railroad Commission (responsible for regulation of refineries in Texas) (512) 463-6748.

- Dianne McCoig (361) 825-3130 at the Texas Natural Resource Conservation Commission (TNRCC).

- David Turner (361) 825-3386 at the Texas Natural Resource Conservation Commission (TNRCC) (team leader in air quality).

- David Bailey (512) 239-6957 of the Texas Natural Resource Conservation Commission (TNRCC) central office in Austin, Texas.
- Gerry Blizzard (512) 239-0991 at the Texas Natural Resource Conservation Commission (TNRCC).
- Mr Diggs and Sherrow of US EPA Region 6 Emission Inventory Group.
- George Lindsey of Environment Canada (506) 452-3286.
- Gerry Turnan of Environment Canada (902) 426-1631.
- Chris Roberts of Environment Canada (NPRI Facilitator for Atlantic Region).
- Mr. Marc Deslauriers of Environment Canada's Pollution Data Branch in Ottawa.
- Peter Hanlon and Chris Vriezen, Water and Sewerage Department, City of Saint John (506) 658-2811.
- Valero Refinery - Mr. Kirk Stoffel of the refinery's Environmental Department
- Mr. Darryl Pupek, Acting Manager, New Brunswick Department of the Environment, Environmental Evaluation Section (506) 457-4844.
- Mr. Matthew Dickson, Engineering Technician, New Brunswick Department of the Environment.
- Mr. Wilf Pilgrim, Air Biologist, Environmental Evaluation Section, New Brunswick Department of the Environment.
- Ms Jill Green, Water and Sewerage Engineer, City of Fredericton (506) 460-2038.

APPENDIX D

VOLATILE ORGANIC COMPOUND (VOC) SCREENING

D-1.0 CHEMICAL SCREENING OF AMBIENT VOLATILE ORGANIC COMPOUND (VOC) CONCENTRATIONS IN EAST SAINT JOHN AIR

D-1.1 Screening Methods

Although data on refinery emissions of specific volatile organic compounds (VOCs) were unavailable, data for ambient VOC air concentrations in East Saint John were available from the Forest Hills monitoring station from 1992 to 1998 (NB DOE, 1999). A chemical screening process was applied to the ambient VOC data to identify chemicals of potential concern to be included in the assessment. For this purpose, it was assumed that the location of the Forest Hills monitoring station adequately represents other locations in East Saint John. It should be recognized that the ambient VOC data would include inputs from a large number of point and mobile sources in Saint John, and would not all be attributable to the IOL Refinery in isolation. It is likely that many of the VOCs measured at the Forest Hills monitoring station are not the result of refinery emissions, but are due to other local industries, vehicle emissions related to traffic, various home heating/wood burning sources and long range transport processes. The approach adopted for VOCs was to quantitatively assess the potential impacts to human health from the concentrations of these substances measured in the Forest Hills monitoring station. The results of this quantitative assessment would then be interpreted based on the magnitude of the predicted potential impacts and a qualitative evaluation of potential sources of VOCs in the region, including the IOL Refinery and the likelihood that the IOL Refinery Upgrade will result in any change in the VOC concentrations currently reported from the ambient monitoring station.

Those VOCs which were measured at the Forest Hills monitoring location from 1996 to 1998 at concentrations greater than the analytical detection limit [*i.e.*, greater than or equal to the analytical limit of quantitation (LOQ)] were selected for screening. While a review of the "acceptability" of the analytical methods and their limits of quantitation is beyond the scope of this assessment, it was assumed that regulatory agency-approved analytical methods were used for samples and that the limits of quantitation were not unreasonably high.

For the VOC screening procedure, the inhalation route of exposure of people was considered the most significant pathway for exposure to VOCs in ambient air. Inhalation exposures, assuming breathing 23 m^3 of air per day by a 70 kg adult, were calculated using the maximum ambient air concentrations of VOCs reported between 1996 and 1998. These exposure rates were compared to exposure limits developed for human receptors by regulatory agencies (*e.g.*, Health Canada, U.S. Environmental Protection Agency) to provide information for the toxic potency screening process.

The rationale for the toxic potency screening process is a follows: the toxic potency of a chemical is represented by the dose or quantity of that chemical which is necessary to produce adverse health effects (*i.e.*, toxic effects). For example, the toxic potency of chemical A would be greater than that of chemical B if toxic effects are produced at a lower concentration of chemical A than chemical B. It is important to consider the toxic potency of chemicals when selecting the chemicals of concern for a risk assessment, because chemicals present at low concentrations with a high toxic potency may pose a greater risk potential to human receptors than chemicals which are present at higher concentrations, but with a lower toxic potency.

The toxic potency screening procedure used in this assessment is similar to that developed by the U.S. Environmental Protection Agency (US EPA, 1989). Exposure limits (*i.e.*, concentrations of chemicals that individuals can be exposed to on a daily basis without developing adverse health effects, or where the risk of incurring adverse health effects is considered to be at an acceptable level), are used as indicators of toxic potency in a toxic potency screening. Human exposure limits were chosen based on the most sensitive endpoints in individuals and adverse health endpoints (*i.e.*, cancer, neurological effects, reproductive effects, *etc.*). In a toxic potency screening process, human health exposure limits are typically expressed as either reference doses or concentrations (RfD or RfC), which indicate concentrations of chemicals that individuals can be exposed to on a daily basis without the occurrence of adverse health effects (used for non-carcinogens), or risk-specific doses or concentrations (RsD or RsC), where the risk of incurring adverse health effects is considered to be at an acceptable level (used for carcinogens). Exposure limits used in the current toxic potency screening process were identified from the following regulatory sources: Health Canada, U.S. EPA Integrated Risk Information System (IRIS) database, U.S. EPA health assessment reports, CalEPA Reference Exposure Levels and Cancer Potency Values, Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels, and the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG).

The relative toxic potency of each of the VOCs was calculated as the ratio between the inhalation exposure based on maximum ambient air concentrations reported at the ambient monitoring station between 1996 and 1998, and the selected inhalation exposure limit. Ranking of the toxic potency yielded a list of VOCs in order of percent contribution to overall toxicity of the total mixture. Those chemicals contributing to 95.0% of the overall toxic potency were selected for inclusion in the quantitative human health risk assessment. This is based on the rationale that if no potential health risks are identified from chemicals representing 95.0% of the total toxic potency, then chemicals contributing 5% or less of the total toxic potency would also be assumed not to pose potential health risks. If the analysis should indicate possible unacceptable health risks from the chemicals contributing 95% of the overall toxic potency, further evaluation of the screening process would be required to include some or all of the chemicals outside the 95% cut-off value.

The ambient air sampling program included analysis for a large number of VOCs, and some of those detected did not have corresponding regulatory air criteria or inhalation exposure limits available. Therefore, to ensure that all measurable VOCs would be included in the toxic potency screening, those VOCs that did not have exposure criteria were grouped, according to similarities in physical/chemical properties, with those that did have exposure criteria.

The chemical groupings for the VOCs measured in Saint John air are as follows (group names are underlined and in italics). Chemicals within the above groups that are considered to be potential carcinogens (according to Health Canada or U.S. EPA) are bolded.

- *Benzene* - **benzene**

- *Toluene* - toluene

- *Ethylbenzene* - ethylbenzene

- *Xylenes* - m and p-xylenes; o-xylenes
- *Styrene* - styrene
- *Alkyl benzenes* - 1,2,3-trimethylbenzene; 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene; 1,2-diethylbenzene; 1,3-diethylbenzene; 1,4-diethylbenzene; hexylbenzene; iso-butylbenzene; isopropylbenzene; n-butylbenzene; n-propylbenzene; sec-butylbenzene; tert-butylbenzene; 2-ethyltoluene; 3-ethyltoluene; 4-ethyltoluene; p-cymene
- *Butadienes* - **1,3-butadiene**; isoprene (2-methyl-1,3-butadiene)
- *Chlorinated benzenes* - 1,4-dichlorobenzene; **benzyl chloride**
- *Aldehyde group* - benzaldehyde; **crotonaldehyde**; hexanal; isovaleraldehyde; m-tolualdehyde; propionaldehyde; p-tolualdehyde; valeraldehyde
- *Acetaldehyde* - **acetaldehyde**
- *Formaldehyde group*: **formaldehyde**, acrolein
- *Ketones* - acetone; MEK (methyl ethyl ketone); MIBK (methyl isobutyl ketone)
- *Chlorinated Alkanes* - 1,1,1-trichloroethane; **1,1,2,2-tetrachloroethane**; **1,1,2-trichloroethane**; 1,1-dichloroethane; **1,2-dichloroethane**; 1,2-dichloropropane; 1,4-dichlorobutane; **carbon tetrachloride**; chloroethane; **chloroform**; **chloromethane**; **dichloromethane**
- *Chlorinated Alkenes* - **1,1-dichloroethylene**; cis-1,2-dichloroethylene; **tetrachloroethylene (PERC**); trans-1,2-dichloroethylene; **trichloroethylene**; **vinyl chloride**
- *Brominated Alkanes* - **bromodichloromethane**; bromomethane; **bromoform**; **dibromochloromethane**; dibromomethane; **EDB (ethylene dibromide or 1,2-dibromoethane**); ethylbromide (bromoethane)
- *Chlorofluorocarbons (CFCs)* - Freon 11; Freon 114; Freon 12; Freon 22
- *Polycyclic Aromatic Hydrocarbons (PAHs)* - naphthalene; indane
- *Aliphatic Hydrocarbons* - Due to the lack of toxicity data for many of these compounds, the measured hydrocarbon VOCs were grouped based on TPHCWG (1996,1997) fractions for aliphatic hydrocarbons [includes linear and branched alkanes, alkenes, alkynes, and cycloalkanes(enes)].
    - C1-C4 Fraction - ethane; butane; isobutane; propane; 1-butene (isobutene); cis-2-butene; trans-2-butene; ethylene; propylene; 1-butyne; acetylene (ethyne)

- C5-C8 Fraction - 2,2,3-trimethylbutane; 2,2,4-trimethylpentane; 2,2-dimethylbutane; 2,2-dimethylhexane; 2,2-dimethylpentane; 2,2-dimethylpropane; 2,2,4-trimethylpentane; 2,3-dimethylbutane; 2,3-dimethylpentane; 2,4-dimethylhexane; 2,4-dimethylpentane; 2,5-dimethylhexane; 2-methylheptane; 2-methylhexane; 2-methylpentane; 3-methylheptane; 3-methylhexane; 3-methylpentane; 4-methylheptane; heptane; hexane; isopentane; octane; pentane; 1-heptene; 1-hexene; 1-octene; 1-pentene; 2-ethyl-1-butene; 2-methyl-1-butene; 2-methyl-2-butene; 3-methyl-1-pentene; 4-methyl-1-pentene; cis-2-octene; cis-2-pentene; cis-3-heptene; cis-3-methyl-2-pentene; cis-4-methyl-2-pentene; cis-2-heptene; cis-2-hexene; trans-2-heptene; trans-2-hexene; trans-2-octene; trans-2-pentene; trans-3-heptene; trans-3-methyl-2-pentene; trans-4-methyl-2-pentene; 1-methylcyclohexene; 1-methylcyclopentene; cis-1,3-dimethylcyclohexane; cis-1,4/t-1,3-dimethylcyclohexane; cyclohexane; cyclohexene; cyclopentane; cyclopentene; methylcyclohexane; methylcyclopentane; trans-1,2-dimethylcyclohexane; trans-1,4-dimethylcyclohexane

- >C8-C10 Fraction - 2,2,5-trimethylhexane; 3,6-dimethyloctane; decane; nonane; 1-decene; 1-nonene

- >C10-C12 Fraction - dodecane; undecane

Once placed within groups, regulatory inhalation exposure limits were identified for the individual chemicals within each group, where possible. These regulatory inhalation exposure limits were identified from Health Canada, US EPA, CalEPA, ATSDR, and the TPHCWG and were applied according to the following hierarchy:

For Non-carcinogens:

1. Health Canada Tolerable Concentrations (TC)
2. US EPA (IRIS or HEAST) Reference Concentrations (RfCs)or Inhalation Reference Doses (RfDi)
3. CalEPA Non-cancer Chronic Inhalation Reference Exposure Levels
4. ATSDR Minimal Risk Levels (MRLs)
5. TPHCWG Reference Concentrations (RfCs)
6. Where no inhalation limits were available from these regulatory agencies, they were derived from regulatory oral exposure limits assuming 100% inhalation bioavailability, and a 70 kg individual with an inhalation rate of 23 m^3/d (Health Canada, 1994).

For Carcinogens

1. US EPA (IRIS or HEAST) Inhalation Unit Risks (IURs)
2. CalEPA Cancer Potency Values
3. Where no inhalation limits were available from these sources, they were derived from US EPA oral exposure limits assuming an acceptable risk level of 1 in 100,000, 100% inhalation bioavailability, and a 70 kg individual with an inhalation rate of 23 m^3/d (Health

Canada, 1994).

For chemicals with no regulatory inhalation or oral exposure limits available, the most conservative exposure limit for a surrogate chemical from the same chemical group was used. In all cases where this was necessary, the surrogate exposure limit used was the most conservative inhalation limit available for the given group. For the toxic potency screen, all individual chemicals with a regulatory exposure limit available were screened as individual chemicals. For the sake of conservatism, if a chemical had both non-carcinogenic and carcinogenic exposure limits available for the inhalation route, it was assumed to act as a carcinogen for the purposes of the toxic potency screen. For those chemicals without regulatory exposure limits, the maximum concentrations were added to the maximum concentration of the surrogate chemical. Table D-1 presents the exposure limits used in the toxic potency screening process.

Table D-1 Exposure Limits Used in the Toxic Potency Screening

VOC Grouping	Chemical	Type of Limit	Exposure Limit	Source
benzene	benzene	IUR[1]	0.0078 $(\text{mg/m}^3)^{-1}$	US EPA, 1999 (IRIS)
toluene	toluene	TC	3800 μg/m^3	Health Canada, 1996
ethylbenzene	ethylbenzene	RfC	1000 μg/m^3	US EPA, 1999 (IRIS)
xylenes	m, p and o-xylenes	TC	180 μg/m^3 (provisional)	Health Canada, 1996
styrene	styrene	TC	92 μg/m^3	Health Canada, 1996
alkyl benzenes	[a]	RfC	[b]200 μg/m^3	Based on TPHCWG, 1996,1997
butadienes	1,3-butadiene	IUR	0.28 $(\text{mg/m}^3)^{-1}$	US EPA, 1999 (IRIS)
	isoprene (2-methyl-1,3-butadiene)	IUR	[c]0.28 $(\text{mg/m}^3)^{-1}$	Based on US EPA, 1999 (IRIS) IUR for 1,3-butadiene
1,4-dichlorobenzene	1,4-dichlorobenzene	TC	95 μg/m^3	Health Canada, 1996
benzyl chloride	benzyl chloride	CPV	0.00004.9 $(\mu\text{g/m}^3)^{-1}$	CalEPA, 1999
C1 to C4 aliphatics	[d]	REL	[e]100 μg/m^3	CalEPA, 1997
C5 to C8 aliphatics	[f]	RfC	[g]18,400 μg/m^3	TPHCWG, 1996,1997
>C8 to C10 aliphatics	[h]	RfC	[i]1000 μg/m^3	TPHCWG, 1996,1997
>C10 to C12 aliphatics	[j]	RfC	[k]1000 μg/m^3	TPHCWG, 1996,1997

Table D-1 Exposure Limits Used in the Toxic Potency Screening

VOC Grouping	Chemical	Type of Limit	Exposure Limit	Source
aldehydes	acetaldehyde	IUR	0.0022 (mg/m^3)$^{-1}$	US EPA, 1999 (IRIS)
	acrolein	RfC	0.02 μg/m^3	US EPA, 1999 (IRIS)
	benzaldehyde	RfD (oral)	[l]100 μg/kg body weight/day	US EPA, 1999 (IRIS)
	crotonaldehyde	SF (oral)	[m]1.9 (mg/kg/d)$^{-1}$	US EPA, 1997 (HEAST)
	formaldehyde	IUR	0.013 (mg/m^3)$^{-1}$	US EPA, 1999 (IRIS)
	hexanal	RfC	[n]0.02 μg/m^3	Based on US EPA, 1999 (IRIS) RfC for acrolein
	isovaleraldehyde	RfC	[n]0.02 μg/m^3	Based on US EPA, 1999 (IRIS) RfC for acrolein
	m-tolualdehyde	RfC	[n]0.02 μg/m^3	Based on US EPA, 1999 (IRIS) RfC for acrolein
	propionaldehyde	RfC	[n]0.02 μg/m^3	Based on US EPA, 1999 (IRIS) RfC for acrolein
	p-tolualdehyde	RfC	[n]0.02 μg/m^3	Based on US EPA, 1999 (IRIS) RfC for acrolein
	valeraldehyde	RfC	[n]0.02 μg/m^3	Based on US EPA, 1999 (IRIS) RfC for acrolein
ketones	acetone	RfD (oral)	[o]100 μg/kg body weight/day	US EPA, 1999 (IRIS)
	MEK (methyl ethyl ketone)	RfC	1000 μg/m^3	US EPA, 1999 (IRIS)
	MIBK (methyl isobutyl ketone)	RfC	80 μg/m^3	US EPA, 1997 (HEAST)
chlorinated alkanes	1,1,1-trichloroethane	RfC	1000 μg/m^3	US EPA, 1999 (IRIS)
	1,1,2,2-tetrachloroethane	IUR	0.058 (mg/m^3)$^{-1}$	US EPA, 1999 (IRIS)
	1,1,2-trichloroethane	IUR	0.016 (mg/m^3)$^{-1}$	US EPA, 1999 (IRIS)
	1,1-dichloroethane	RfC	500 μg/m^3	US EPA, 1997 (HEAST)

Table D-1 Exposure Limits Used in the Toxic Potency Screening

VOC Grouping	Chemical	Type of Limit	Exposure Limit	Source
	1,2-dichloroethane	IUR	0.026 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	1,2-dichloropropane	RfC	4 $\mu g/m^3$	US EPA, 1999 (IRIS)
	1,4-dichlorobutane	RfC	[p]4 $\mu g/m^3$	Based on US EPA, 1999 (IRIS) RfC for 1,2-dichloropropane
	carbon tetrachloride	IUR	0.015 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	chloroethane (ethyl chloride)	RfC	10,000 $\mu g/m^3$	US EPA, 1999 (IRIS)
	chloroform	IUR	0.023 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	chloromethane	IUR	0.0018 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	dichloromethane (methylene chloride)	IUR	0.00047 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
chlorinated alkenes	1,1-dichloroethylene	IUR	0.05 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	cis-1,2-dichloroethylene	RfD (oral)	[q]10 μg/kg body weight/day	US EPA, 1997 (HEAST)
	tetrachloroethylene (PERC)	IUR	0.00058 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	trans-1,2-dichloroethylene	RfD (oral)	[r]20 μg/kg body weight/day	US EPA, 1999 (IRIS)
	trichloroethylene	IUR	0.0017 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	vinyl chloride	IUR	0.084 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
brominated alkanes	bromodichloromethane	SF(oral)	[s]0.062 $(mg/kg/d)^{-1}$	US EPA, 1999 (IRIS)
	bromomethane	RfC	5 $\mu g/m^3$	US EPA, 1999 (IRIS)
	bromoform	IUR	0.0011 $(mg/m^3)^{-1}$	US EPA, 1999 (IRIS)
	dibromochloromethane	SF (oral)	[t]0.084 $(mg/kg/d)^{-1}$	US EPA, 1999 (IRIS)
	dibromomethane	RfD (oral)	[u]10 μg/kg body weight/day	US EPA, 1997 (HEAST)
	EDB (ethylene dibromide or 1,2-dibromoethane)	IUR	0.22 $(mg/m^3)^{-1}$	US EPA, 1997 (HEAST)
	ethylbromide (bromoethane)	IUR	[v]0.22 $(mg/m^3)^{-1}$	Based on US EPA, 1997 (HEAST) IUR for EDB

Table D-1 Exposure Limits Used in the Toxic Potency Screening

VOC Grouping	Chemical	Type of Limit	Exposure Limit	Source
CFCs	Freon 11 (trichlorofluoromethane)	RfC	700 $\mu g/m^3$	US EPA, 1997 (HEAST)
	Freon 114 (tetrafluorodichloroethane)	RfC	[w]200 $\mu g/m^3$	US EPA, 1997 (HEAST)
	Freon 12 (dichlorodifluoromethane)	RfC	200 $\mu g/m^3$	US EPA, 1997 (HEAST)
	Freon 22 (chlorodifluoromethane)	RfC	50,000 $\mu g/m^3$	US EPA, 1999 (IRIS)
PAHs	naphthalene	RfC	3 $\mu g/m^3$	US EPA, 1999 (IRIS)
	indane	RfC	[x]3 $\mu g/m^3$	Based on US EPA, 1999 (IRIS) RfC for naphthalene

Notes: IUR = Inhalation Unit Risk; TC = Tolerable Concentration; RfC = Reference Concentration; CPV = Cancer Potency Value; REL = Reference Exposure Level; RfD = Reference Dose; SF = Slope Factor

[1] For the toxic potency screening, IUR's were converted to air concentrations (in $\mu g/m^3$) assuming a 1 in 100,000 (1×10^{-5}) acceptable risk level and by applying the following equation: $(1 \times 10^{-5} / \text{IUR}) \times 1000 =$ concentration in $\mu g/m^3$.

[a] The alkyl benzene group consists of the following chemicals: 1,2,3-trimethylbenzene; 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene; 1,2-diethylbenzene; 1,3-diethylbenzene; 1,4-diethylbenzene; hexylbenzene; iso-butylbenzene; isopropylbenzene; n-butylbenzene; n-propylbenzene; sec-butylbenzene; tert-butylbenzene; 2-ethyltoluene; 3-ethyltoluene; 4-ethyltoluene; p-cymene. The maximum concentrations of each group member were summed and the total concentration was compared to the selected exposure limit in the toxic potency screening.

[b] As no exposure limits were identified for the individual chemicals within the alkyl benzene group, the TPHCWG (1996; 1997) fraction-specific RfC of 200 $\mu g/m^3$ is used to represent the RfC for all chemicals within this group. This RfC is based on RfC values of 200 $\mu g/m^3$ for >C8 to C16 aromatics.

[c] As no exposure limit was identified for isoprene, the IUR for 1,3-butadiene (US, EPA, 1999 (IRIS)) is used to represent the IUR for isoprene.

[d] The C1 to C4 aliphatics group consists of the following chemicals: ethane; butane; isobutane; propane; 1-butene (isobutene); cis-2-butene; trans-2-butene; ethylene; propylene; 1-butyne; acetylene (ethyne). The maximum concentrations of each group member were summed and the total concentration was compared to the selected exposure limit in the toxic potency screening.

[e] No exposure limits were identified for the individual chemicals within the C1 to C4 aliphatics group with the exception of CalEPA (1997) RELs for ethylene (100 $\mu g/m^3$) and propylene (3000 $\mu g/m^3$). The more conservative limit of 100 $\mu g/m^3$ is used to represent all chemicals within this group.

[f] The C5 to C8 aliphatics group consists of the following chemicals: 2,2,3-trimethylbutane; 2,2,4-trimethylpentane; 2,2-dimethylbutane; 2,2-dimethylhexane; 2,2-dimethylpentane; 2,2-dimethylpropane; 2,2,4-trimethylpentane; 2,3-dimethylbutane; 2,3-dimethylpentane; 2,4-dimethylhexane; 2,4-dimethylpentane; 2,5-dimethylhexane; 2-methylheptane; 2-methylhexane; 2-methylpentane; 3-methylheptane; 3-methylhexane; 3-methylpentane; 4-methylheptane; heptane; hexane; isopentane; octane; pentane; 1-heptene; 1-hexene; 1-octene; 1-pentene; 2-ethyl-1-butene; 2-methyl-1-butene; 2-methyl-2-butene; 3-methyl-1-pentene; 4-methyl-1-pentene; cis-2-octene; cis-2-pentene; cis-3-heptene; cis-3-methyl-2-pentene; cis-4-methyl-2-pentene; cis-2-heptene; cis-2-hexene; trans-2-heptene; trans-2-hexene; trans-2-octene; trans-2-pentene; trans-3-heptene; trans-3-methyl-2-pentene; trans-4-methyl-2-pentene; 1-

methylcyclohexene; 1-methylcyclopentene; cis-1,3-dimethylcyclohexane; cis-1,4/t-1,3-dimethylcyclohexane; cyclohexane; cyclohexene; cyclopentane; cyclopentene; methylcyclohexane; methylcyclopentane; trans-1,2-dimethylcyclohexane; trans-1,4-dimethylcyclohexane. The maximum concentrations of each group member were summed and the total concentration was compared to the selected exposure limit in the toxic potency screening.

[g] As only a few exposure limits were identified for the individual chemicals within the C5 to C8 aliphatics group, the TPHCWG (1996; 1997) fraction-specific RfC of 18,400 $\mu g/m^3$ is used to represent the RfC for all chemicals within this group.

[h] The >C8 to C10 aliphatics group consists of the following chemicals: 2,2,5-trimethylhexane; 3,6-dimethyloctane; decane; nonane; 1-decene; 1-nonene. The maximum concentrations of each group member were summed and the total concentration was compared to the selected exposure limit in the toxic potency screening.

[i] As no exposure limits were identified for the individual chemicals within the >C8 to C10 aliphatics group, the TPHCWG (1996; 1997) fraction-specific RfC of 1000 $\mu g/m^3$ is used to represent the RfC for all chemicals within this group.

[j] The >C10 to C12 aliphatics group consists of the following chemicals: dodecane, undecane. The maximum concentrations of each group member were summed and the total concentration was compared to the selected exposure limit in the toxic potency screening.

[k] As no exposure limits were identified for the individual chemicals within the >C10 to C12 aliphatics group, the TPHCWG (1996; 1997) fraction-specific RfC of 1000 $\mu g/m^3$ is used to represent the RfC for all chemicals within this group.

[l] Only an oral RfD is available for benzaldehyde. For the toxic potency screen, this oral RfD was converted to an air concentration ($\mu g/m^3$) assuming 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada, 1994)according to the following equation: RfD ($\mu g/kg/d$) x 70 kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[m] Only an oral slope factor is available for trans-crotonaldehyde. For the toxic potency screen, this oral SF was converted to an air concentration ($\mu g/m^3$) assuming a 1×10^{-5} acceptable risk level, 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada, 1994)according to the following equation: $(1 \times 10^{-5} / SF) \times 1000 \times 70$ kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[n] As no exposure limits were identified for hexanal, isovaleraldehyde, m-tolualdehyde, propionaldehyde, p-tolualdehyde, or valeraldehyde, the RfC for acrolein was used to conservatively represent the RfC for these chemicals.

[o] Only an oral RfD is available for acetone. For the toxic potency screen, this oral RfD was converted to an air concentration ($\mu g/m^3$) assuming 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada, 1994)according to the following equation: RfD ($\mu g/kg/d$) x 70 kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[p] As no exposure limit was identified for 1,4-dichlorobutane, the RfC for 1,2-dichloropropane (US, EPA, 1999 (IRIS)) is used to represent the RfC for 1,4-dichlorobutane.

[q] Only an oral RfD is available for cis-1,2-dichloroethylene. For the toxic potency screen, this oral RfD was converted to an air concentration ($\mu g/m^3$) assuming 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada, 1994)according to the following equation: RfD ($\mu g/kg/d$) x 70 kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[r] Only an oral RfD is available for trans-1,2-dichloroethylene. For the toxic potency screen, this oral RfD was converted to an air concentration ($\mu g/m^3$) assuming 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada, 1994)according to the following equation: RfD ($\mu g/kg/d$) x 70 kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[s] Only an oral slope factor is available for bromodichloromethane. For the toxic potency screen, this oral SF was converted to an air concentration ($\mu g/m^3$) assuming a 1×10^{-5} acceptable risk level, 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada, 1994)according to the following equation: $(1 \times 10^{-5} / SF) \times 1000 \times 70$ kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[t] Only an oral slope factor is available for dibromochloromethane. For the toxic potency screen, this oral SF was converted to an air concentration ($\mu g/m^3$) assuming a 1×10^{-5} acceptable risk level, 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of $23 m^3/d$ (Health Canada,

1994)according to the following equation: (1 x 10^{-5} / SF) x 1000 x 70 kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[u] Only an oral RfD is available for dibromomethane. For the toxic potency screen, this oral RfD was converted to an air concentration ($\mu g/m^3$) assuming 100% inhalation bioavailability, a 70 kg individual, and a breathing rate of 23m^3/d (Health Canada, 1994)according to the following equation: RfD ($\mu g/kg/d$) x 70 kg ÷ 23 m^3/d = air concentration ($\mu g/m^3$).

[v] As no exposure limit was identified for ethylbromide, the IUR for ethylene dibromide (US, EPA, 1999 (IRIS)) is used to represent the IUR for ethylbromide.

[w] As no exposure limit was identified for Freon 114, the most conservative exposure limit of 200 $\mu g/m^3$ for CFCs is used to represent Freon 114.

[x] As no exposure limit was identified for indane, the RfC for naphthalene (US, EPA, 1999 (IRIS)) is used to represent the RfC for indane.

D-2.0 SCREENING RESULTS

Results of the toxic potency screening are presented in Table D-2. Based on the toxic potency screening results, the following chemicals / chemical groups were carried forward for further evaluation:

- aldehyde group (includes: benzaldehyde; crotonaldehyde; hexanal; isovaleraldehyde; m-tolualdehyde; propionaldehyde; p-tolualdehyde; valeraldehyde)[1]
- formaldehyde group: (includes formaldehyde, acrolein)
- butadiene group (includes: 1,3-butadiene, isoprene)
- benzene
- toluene[2]
- ethylbenzene[2]
- xylenes[2]

[1] All members of the aldehyde group that were detected at measurable concentrations were conservatively carried forward for detailed assessment, regardless of whether or not individual aldehydes contributed to >95% of the toxic potency of all VOCs screened.

[2] Chemical did not fall within the top 95% toxic potency of all VOCs screened; however this chemical was carried forward for further assessment based on public concern.

Table D-2 Toxic Potency Screening Results for Ambient VOC Air Concentrations[1]

Chemical or Group	Maximum Air Concentration (ug/m3)	Exposure Limits (expressed as air concentrations (ug/m3))	Maximum Air Concentration / Exposure Limit	Contribution to Toxic Potency	Cumulative Toxic Potency
propionaldehyde	1.33	0.02	66.5	25.58479075	25.58479075
acrolein	0.69	0.02	34.5	13.2733125	38.85810325
valeraldehyde	0.52	0.02	26	10.00307608	48.86117934
isoprene	0.86	0.036	23.88888889	9.190860505	58.05203984
hexanal	0.46	0.02	23	8.848874998	66.90091484
isovaleraldehyde	0.44	0.02	22	8.464141302	75.36505614
1,3-butadiene	0.54	0.036	15	5.771005433	81.13606157
crotonaldehyde	0.28	0.02	14	5.386271738	86.52233331
m-tolualdehyde	0.18	0.02	9	3.46260326	89.98493657
formaldehyde	5.14	0.77	6.675324675	2.568222331	92.5531589
p-tolualdehyde	0.08	0.02	4	1.538934782	94.09209368
benzene	5.06	1.3	3.892307692	1.497501923	95.58959561
C1 to C4 aliphatics	169.52	100	1.6952	0.652200561	96.24179617
acetaldehyde	6.19	4.5	1.375555556	0.529222572	96.77101874
ethylene dibromide	0.06	0.045	1.333333333	0.512978261	97.283997
carbon tetrachloride	0.76	0.67	1.134328358	0.436414341	97.72041134
benzyl chloride	0.21	0.204	1.029411765	0.396049392	98.11646073
ethyl bromide	0.04	0.045	0.888888889	0.341985507	98.45844624
chloroform	0.22	0.43	0.511627907	0.196840495	98.65528674
1,1-dichloroethylene	0.1	0.2	0.5	0.192366848	98.84765359
1,2-dichloroethane	0.18	0.38	0.473684211	0.182242277	99.02989586
naphthalene	1.13	3	0.376666667	0.144916359	99.17481222
1,1,2,2-tetrachloroethane	0.06	0.17	0.352941176	0.135788363	99.31060058
dichloromethane	6.26	21.3	0.293896714	0.113071969	99.42367255
1,1,2-trichloroethane	0.17	0.63	0.26984127	0.103817029	99.52748958
bromodichloromethane	0.13	0.49	0.265306122	0.102072205	99.62956179
dibromochloromethane	0.08	0.36	0.222222222	0.085496377	99.71505816
chloromethane	1.22	5.6	0.217857143	0.083816984	99.79887515
vinyl chloride	0.02	0.12	0.166666667	0.064122283	99.86299743

Table D-2 Toxic Potency Screening Results for Ambient VOC Air Concentrations[1]

Chemical or Group	Maximum Air Concentration (ug/m3)	Exposure Limits (expressed as air concentrations (ug/m3))	Maximum Air Concentration / Exposure Limit	Contribution to Toxic Potency	Cumulative Toxic Potency
indane	0.21	3	0.07	0.026931359	99.88992879
xylenes	7.07	180	0.039277778	0.015111485	99.90504027
bromomethane	0.18	5	0.036	0.013850413	99.91889069
alkyl benzenes	6.72	200	0.0336	0.012927052	99.93181774
1,4-dichlorobutane	0.11	4	0.0275	0.010580177	99.94239791
tetrachloroethylene	0.36	17.2	0.020930233	0.008052566	99.95045048
trichloroethylene	0.12	5.9	0.020338983	0.007825092	99.95827557
acetone	5.53	304	0.018190789	0.00699861	99.96527418
Freon 12	3.2	200	0.016	0.006155739	99.97142992
1,2-dichloropropane	0.06	4	0.015	0.005771005	99.97720093
bromoform	0.12	9.1	0.013186813	0.005073411	99.98227434
C5 to C8 aliphatics	192.9	18,400	0.010483696	0.004033431	99.98630777
toluene	20.43	3800	0.005376316	0.00206845	99.98837622
>C8 to C10 aliphatics	4.17	1000	0.00417	0.00160434	99.98998056
dibromomethane	0.12	30.4	0.003947368	0.001518686	99.99149924
Freon 11	2.11	700	0.003014286	0.001159697	99.99265894
>C10 to C12 aliphatics	2.7	1000	0.0027	0.001038781	99.99369772
1,4-dichlorobenzene	0.25	95	0.002631579	0.001012457	99.99471018
methyl isobutyl ketone	0.19	80	0.002375	0.000913743	99.99562392
styrene	0.2	92	0.002173913	0.000836378	99.9964603
cis-1,2-dichloroethylene	0.06	30.4	0.001973684	0.000759343	99.99721964
ethylbenzene	1.64	1000	0.00164	0.000630963	99.99785061
benzaldehyde	0.41	304	0.001348684	0.000518884	99.99836949
methyl ethyl ketone	1.26	1000	0.00126	0.000484764	99.99885425
Freon 114	0.24	200	0.0012	0.00046168	99.99931593
trans-1,2-dichloroethylene	0.06	60.9	0.000985222	0.000379048	99.99969498
1,1,1-trichloroethane	0.65	1000	0.00065	0.000250077	99.99994506
1,1-dichloroethane	0.06	500	0.00012	0.000046168	99.99999123
Freon 22	0.64	50000	0.0000128	0.00000492459	99.99999615

Table D-2 Toxic Potency Screening Results for Ambient VOC Air Concentrations[1]

Chemical or Group	Maximum Air Concentration (ug/m3)	Exposure Limits (expressed as air concentrations (ug/m3))	Maximum Air Concentration / Exposure Limit	Contribution to Toxic Potency	Cumulative Toxic Potency
chloroethane	0.1	10000	0.00001	0.00000384734	100
SUM			259.9200464	100	200

[1] The significant figures used were as reported in the analytical data from the ambient monitoring station. CANTOX ENVIRONMENTAL INC. did not modify the reported data with respect to reported significant figures

Shading indicates chemicals which were carried forward for further evaluation based on 95% contribution to total toxic potency.

Note: The cutoff value for cumulative percent contribution to total toxic potency rarely equals exactly 95%. Thus, the cutoff point for carrying chemicals forward for further evaluation was the first value which captured 95% of the total toxic potency.

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APPENDIX E

TECHNICAL INFORMATION RELATED TO THE EXPOSURE ASSESSMENT

E-1.0 INTRODUCTION TO APPENDIX E

This appendix provides technical information related to the quantitative human health risk assessment associated with potential exposures to the volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) chemicals emitted into the air shed surrounding the Irving Oil Limited (IOL) facility.

The estimation of exposure to chemicals of concern at the site was based on the following parameters:

- the chemical-specific physical, chemical and biological factors that determine the ability of the organism to take the chemicals into the body;
- the chemical-specific physical/chemical characteristics which determine the interaction and behaviour of a chemical with its surrounding environment (*e.g.,* water solubility, volatility, tendency to bind to particles);
- the characteristics of the site and surrounding area;
- the characteristics of the environmental compartments at the site (*e.g.,* air, soil, subsurface soil and water), as well as the quantities of chemicals entering the compartments from various sources, and their persistence in these compartments;
- the behavioural and lifestyle characteristics of the human receptors that determine the actual exposures through interactions of the receptors with the various pathways (*e.g.,* respiration rate, body weight); and,
- the equations and algorithms used to predict exposures to the receptors.

Future exposure estimates were largely based on air dispersion analyses conducted by Stantec (1999a,b). This analysis used a computer model developed by the US Environmental Protection Agency (EPA) called the Industrial Source Complex Short Term (ISCST3) model.

Briefly, stack emission rates for particulate matter (PM) and sulphur dioxide (SO_2) were used in the ISCST3 model, along with site-specific information related to weather patterns, wind speed, topography, *etc.*, for the Saint John area. In addition, site specific information related to the IOL Refinery (such as stack heights, *etc.*) were used. The results of this computer analysis are predicted ground level air concentrations for SO_2 and PM at various locations near the refinery. These data were then used in the PHRA to estimate potential future impacts to health.

In addition to predicting future concentrations associated with the Upgraded IOL Refinery, Stantec (1999a,b) also predicted current existing concentrations for SO_2 and PM. These predictions of existing concentrations can be compared against actual air data from air monitoring programs to essentially "correct" the future predictions.

The CEI/HRMG study team used the Stantec (1999a,b) data to estimate possible future concentrations of other substances (such as PAH, NOx, CO), since future estimates for these substances were not otherwise available. The study team felt the future estimates for these additional substances were important since these compounds are typically associated with refinery emissions.

E-2.0 PROBABILISTIC ANALYSIS APPROACH

Probabilistic (also known as stochastic) analysis techniques are included in the current risk assessment to provide a clearer understanding of the uncertainty in the characterization of potential health risks, and to improve the reliability and understanding of potential risks associated with upper-bound and worst-case exposure/hazard scenarios (Thompson *et al.*, 1992; Whitmyre *et al.*, 1992a,b). The use of probabilistic techniques has been recommended by regulatory agencies such as the U.S. EPA (1992). This analysis technique allows the input of probability density functions (probability distributions), where appropriate, in place of point estimates while carrying out estimations of risk. The results of such modelling are presented as cumulative probability density functions that characterize risks, rather than point estimates of the risks that are based on individual, specifically-assigned variables. For the current assessment, the characterization of potential health risks using probabilistic analysis techniques were based on 5,000 iterations of the model.

In using probabilistic analytical techniques in risk assessment, considerable care must be exercised in the adoption of probability distributions for the model variables. Models for the treatment of uncertainty can be based on probabilistic, parametric or switch-over assessment techniques. Parametric sensitivity analysis refers to the examination of the effect on a model output by deterministic changes to the uncertainty quantity. Switch-over analysis techniques involve the analytical or numerical examination of the model to determine the specific magnitude of the input variable that produces optimal decision changes in model output. Probabilistic analysis involves the determination of the amount of uncertainty in model conclusions attributable to a particular input parameter, using correlation, rank correlation, regression and other statistical means (Morgan *et al.*, 1990).

It is important to classify the uncertainty of values in terms of the types of quantities the values represent, since this will determine how the uncertainty should be evaluated. Although subjective probability distributions are often used to describe uncertainty, the probabilistic treatment of uncertainty is appropriate only for types of information that have "empirical or chance" properties (*i.e.*, they are estimates of some "true" value). Decision, value or policy variables, on the other hand, are quantities over which the decision maker has control. Probability distributions should not be assigned to decision variables, since the "true" value of the variable is not a constant, but is defined by the decision maker. The uncertainty of decision variables is better analyzed by other methods (*e.g.*, switch-over analyses). Model domain parameters are decision variables, and should not be "assigned" probability distribution functions (Morgan *et al.*, 1990). Fiering *et al.* (1984) also discuss the problems of increases in the degree of uncertainty arising from smaller uncertainties linked in chains of random variables.

In risk assessment, there are four main sources of uncertainty:

- *Parameter uncertainty*, including random measurement and systematic error, statistical variation, subjective judgement, and inherent randomness or unpredictability (Vesely and Rasmuson, 1984; Covello *et al.*, 1987; Morgan *et al.*, 1990; U.S. EPA, 1992).

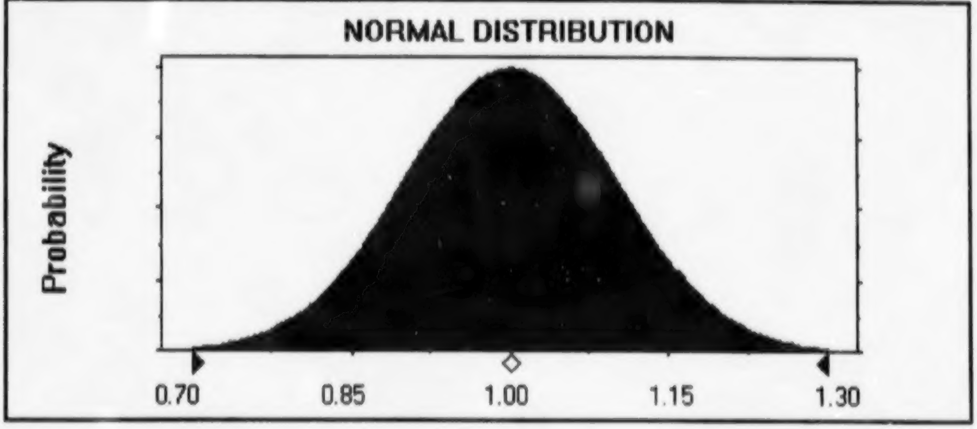
- *Model uncertainty* related to the limitations of numerical models in representing the real world, and arising from surrogate variables, excluded variables, abnormal conditions and incorrect model assumptions and form (Vesely and Rasmuson, 1984; Morgan *et al.*, 1990; U.S. EPA, 1992).

- *Decision rule uncertainty* is related to the measure used to describe risk. It is related to ambiguity or controversy in risk acceptability, perceptions, and social objectives or attitudes (Covello *et al.*, 1987; Morgan *et al.*, 1990). Uncertainties in scenario definition (U.S. EPA, 1992) and value parameters chosen (Morgan *et al.*, 1990) are also decision rules.

- *Variability* in empirical properties are due to uncertainty in measurement (*e.g.*, sampling from a frequency distribution), and/or related to incomplete scientific or technical information (Fiering *et al.*, 1984; Covello *et al.*, 1987; Morgan *et al.*, 1990). Uncertainty due to variability related to sampling can be reduced by desegregation (Morgan *et al.*, 1990) (*i.e.*, dividing age groupings into smaller intervals to reduce variability in body weight). Scientific uncertainty can only be reduced by gathering additional data.

For the current risk assessment, four types of probability density functions (probability distributions) were utilized, those being normal distributions, continuous uniform distributions, log normal distributions, and triangular distributions (see Figures E-2.1 through E-2.4). When data were not available to characterize a probability distribution, or a particular variable was deemed inappropriate for a probability distribution, then a deterministic point estimate value was used.

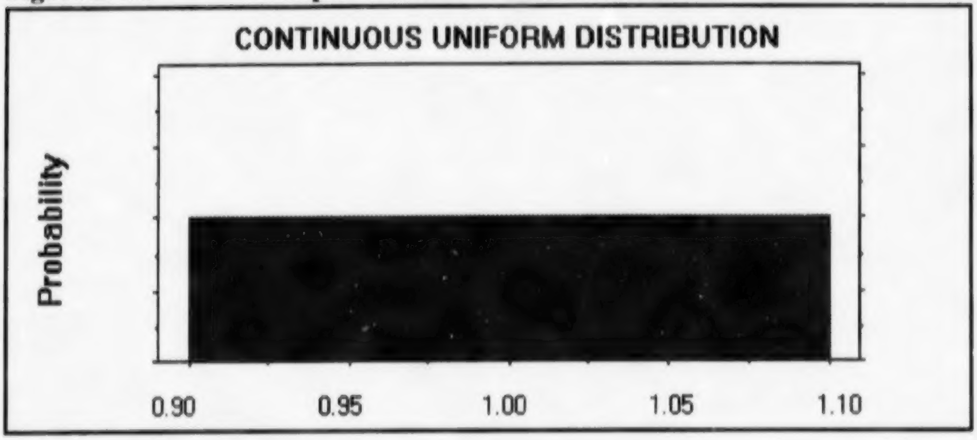
Figure E-2.1 Sample Normal Distributions



Normal Distributions

The most important distribution in probability theory is the normal distribution since it describes many natural phenomena. In order for a variable to be normally distributed, some value of the variable must be the most likely to occur (*i.e.,* the mean of the distribution), the variable must be symmetrically distributed about the mean, and the probability of the variable falling near the mean must be greater than the probability of it falling away from the mean (*i.e.,* there is a 68% chance that the value is within 1 standard deviation of the mean). In addition, minimum and maximum values can be defined for a normal distribution. The normal distribution illustrated in Figure E-2.1 has a mean of 1.00, a standard deviation of 0.1, a minimum value of 0.70 and a maximum of 1.30.

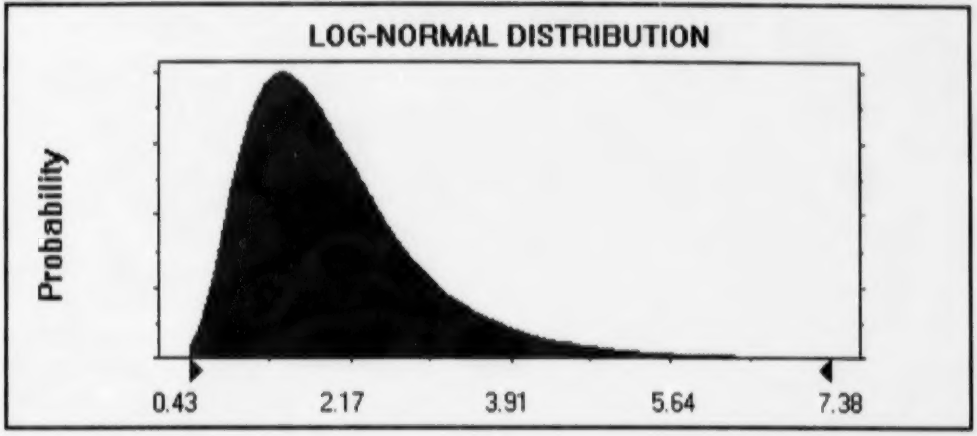
Figure E-2.2 **Sample Continuous Uniform Distribution**



Continuous Uniform Distributions

In a continuous uniform distribution, all values between a minimum and maximum have an equal likelihood of occurring at any particular sampling of the event. The uniform distribution demonstrated in Figure E-2.2 assumes that all values between 0.9 and 1.1 have an equal probability of occurrence. This type of distribution provides a conservative estimate for a variable which has no definable mean value or standard deviation, or where the mean and standard deviations are not known.

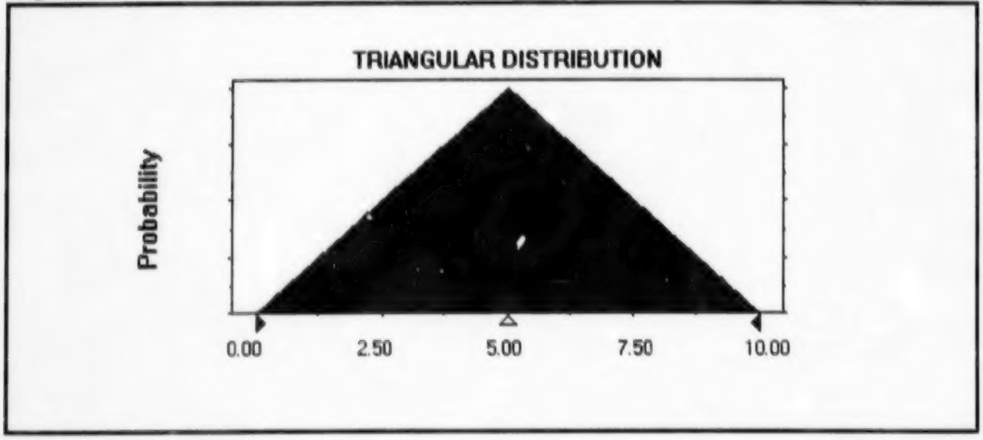
Figure E-2.3 **Sample Log-Normal Distribution**



Log Normal Distributions

The log-normal distribution is widely used in situations where values are positively skewed (*i.e.*, most of the values occur near the minimum value). In order for a variable to be log-normally distributed the variable can increase without limits but can not fall below zero, the variable is positively skewed with most of the values near the lower limit, and the natural logarithm of the variable yields a normal distribution. For example the log-normal distribution illustrated in Figure E-2.3 has a mean of 2.00, and a standard deviation of 1.00.

Figure E-2.4 Sample Triangular Distribution



Triangular Distributions

The triangular distribution is used to describe a situation where a minimum, a maximum and a 'most likely' value are known. In this case, the 'most likely' number falls between the minimum and maximum values, forming a triangular-shaped distribution, which shows that values near the minimum and maximum are less likely to occur than those near the 'most likely' value. This distribution is similar to a normal distribution, and should be used in place of a normal curve when information regarding the shape (*i.e.,* the standard deviation) of the curve is not known. Figure E-2.4 illustrates a triangular distribution with a minimum value of 0, a maximum value of 10 and a 'most likely' value of 5.

E-3.0 ASSUMPTIONS REGARDING THE DERIVATION OF PAH AND VOC AIR CONCENTRATIONS WITHIN THE SAINT JOHN AIR SHED

E-3.1 Introduction

As discussed previously, an important element of the risk assessment process is the assessment of chemical exposure. The purpose of an exposure assessment is to quantify the potential intake of chemicals of concern by representative human receptors (refer to section E-4.0 for detailed receptor information). Results of both the exposure and toxicity assessments are integrated to form the basis of risk characterization which, in turn, can be used to identify human health issues of potential significance. However, before an exposure analysis can be completed, chemical concentrations in various environmental media (*e.g.*, soil, indoor air, indoor dust and vegetation), immediately surrounding the facility, are estimated. The derivation of site-specific environmental media concentrations and associated human exposure estimates are discussed in detail throughout the following sections of this appendix.

E-3.2 Estimating Chemical-Specific Media Concentrations

As previously discussed in the main report, the current risk assessment evaluated four different exposure scenarios:

i) Background chemical concentrations from St. Andrews, Pt. Lepreau and other urban/rural areas;

ii) Existing ambient chemical concentrations measured in the air of Saint John, N.B. (polycyclic aromatic hydrocarbons, volatile organic compounds and total suspended particulate measured in the Forest Hill area);

iii) Existing chemical concentrations in the air as defined by atmospheric modelling of the immediate study area, and

iv Future chemical concentrations in the air as defined by atmospheric modelling of the immediate study area.

For each of the four exposure scenarios, quantitative human exposure estimates to various polycyclic aromatic hydrocarbons (PAHs) and volatile organic chemicals (VOCs) were derived. It should be noted that for exposure scenario ii, environmental media concentrations (*e.g.*, soil, dusts, vegetation) were estimated based on measured air concentration data sets (*i.e.*, measured PAHs and VOCs in the Forest Hill area), while environmental media concentrations for scenarios iii and iv, (with the exception of drinking water), were estimated based on both measured and modelled air concentration data sets provided by New Brunswick DOE (NB DOE, 1999), and Stantec (1999a).

Ambient air monitoring programs can identify and quantify large numbers of VOCs, for which no regulatory air criteria or inhalation exposure limits are available. In order to ensure that all VOCs were accounted for, individual chemicals were grouped according to similarities in physical/chemical properties and toxicological properties. For the current quantitative assessment, the following VOC groups were assessed:

- v) Benzene
- vi) Toluene
- vii) Ethylbenzene
- viii) Xylene (containing m and p-xylenes and o-xylene)
- ix) Butadiene Group (containing 1,3-Butadiene, Isoprene (background scenario only) and 2-methyl-1,3-butadiene)
- x) Aldehyde group (containing acetaldehyde, acrolein, benzaldehyde, crotonaldehyde, formaldehyde, hexanal, isovaleraldehyde, m-tolualdehyde, propionaldehyde, p-tolualdehyde and valeraldehyde)
- xi) Methyl-tert-butyl-ether (MTBE)

PAHs were assessed using both the Whole Mixture Model (WMM) and the Individual PAH Model (IPM) (MOEE, 1997). These approaches are further described in Appendix G. As described in Appendix G, individual PAHs were placed into surrogate groups, based on their known physical-chemical and toxicological properties. The following PAH surrogate groups were quantitatively assessed using the IPM methodology:

- i) Anthracene Group
- ii) Benzo[a]pyrene Group (IPM) and (WMM)
- iii) Fluorene Group
- iv) Naphthalene Group

PAH and VOC equivalency concentrations were used to assess the potential exposure to chemicals within each scenario, and therefore helped to identify potential human health impacts. Initially, individual PAHs and VOCs were first placed into their appropriate surrogate groups. In the case of VOCs, the sum of all group members (*i.e.,* individual VOCs) were reported as the surrogate group concentration. For PAHs, individual chemicals had a specific toxic equivalency factor applied, as discussed in Appendix G. These chemicals were then summed to generate a total surrogate group concentration. Details regarding how PAH and VOC surrogate group concentrations were derived are provided in Appendices G and D, respectively.

E-3.2.1 Background Environmental Media Data

In order to quantify potential exposure and associated human health impacts to chemical concentrations present at other urban locations which are not impacted by the IOL facility and/or other similar industrial sources, ambient air data representing background air quality were compiled. Ambient air data from monitoring stations located in St. Andrews, Pt. Lepreau, and Fredericton, N.B., were reviewed to identify background air quality. However, after closer inspection of these data, it was determined that some additional sources of background data were required for specific chemicals. Background PAH air data, specific to the New Brunswick area were provided by the New Brunswick DOE (1999) and were taken from monitoring locations in the St. Andrews area. This data set represented approximately 65, 24-hour average air samples for a wide variety of PAHs. For the purpose of statistical analysis, those samples which were identified as being below the method of detection were conservatively assumed to be equal to the detection limit. Monitoring stations at Pt. Lepreau supplied background VOC air data, specific to the New Brunswick area and were provided by the New Brunswick DOE (1999). This data set represented approximately 108 individual 24-hour average air samples for a number of different volatile organic compounds between the years 1995 and 1999. As with the PAH data, those samples which were identified as being below the method of detection were conservatively assumed to be equal to the detection limit.

Background concentrations of various PAHs and VOCs in air, surface water and soil were reported by a variety of regulatory agencies (CCME, 1992; MOEE, 1997; CalEPA, 1997; GC/EC/HC, 1992) and other scientific literature (Dann, 1990, 1996; Benoit *et al.*, 1979; Brodzinsky and Singh, 1982) at other urban and rural locations across Canada and the United States. These data were used to represent background air, soil and water quality where New Brunswick-specific monitoring data were lacking or unavailable.

The 95th percentile background air concentrations were used in the point estimate assessment, while lognormal distributions were applied to data sets for use in the stochastic analysis. Generally, when background soil and surface water data were reported as a range, a continuous, uniform distribution within the background probabilistic (*i.e.*, stochastic) assessment was applied. Background environmental media concentrations used in the current assessment are provided in Appendix F.

E-3.3 Derivation of Air Concentrations Used Within the Existing Ambient Scenario

Ambient air data from monitoring stations located in Saint John, N.B., were used to represent baseline air quality (*i.e.*, the existing air quality in Saint John prior to operation of the upgraded IOL refinery). The ambient air quality data, provided by the New Brunswick DOE (1999), characterizes air concentrations for CO, NO_2, SO_2, TSP (PM_{10} and $PM_{2.5}$), and VOCs currently and historically observed in the Saint John area.

Ambient VOC Air Concentrations

The ambient VOC air monitoring data provided by New Brunswick DOE (1999) were used to represent the current air quality in Saint John, N.B. Of the three monitoring locations of concern (*i.e.*, Forest Hills, Silver Falls and Champlain Heights), Forest Hills, N.B. was the only location where VOC air monitoring data were available. Therefore, efforts were focussed on estimating human exposures to chemicals of concern identified at this particular ambient air monitoring location.

The New Brunswick DOE (1999) provided historical VOC air concentrations (ug/m^3) at the Saint John - Forest Hills monitoring location, between the years 1991 and 1998. One or more 24-hour average air concentrations were reported for a variety of VOCs during each month of each year. In order to capture the air quality currently experienced in Saint John, only the last three years of ambient air monitoring data (*i.e.*, 1996, 1997 and 1998) were used. These data represented approximately 100 individual 24-hour-average air concentrations for each VOC of concern. It was believed that using the complete historical data set (*i.e.*, the last eight years of monitoring data) would not provide an accurate representation of the existing air shed conditions in the Saint

John area. However, the last three years of monitoring data were considered sufficient to capture the existing conditions of the Saint John air shed, without being skewed by any one particular year, which may have represented abnormal conditions.

Based on the last three years of air monitoring data, individual chemicals of concern were isolated from the list of VOCs provided by New Brunswick DOE (1999) and placed into their surrogate groups. Means, standard deviations and 95th percentile air concentrations were calculated for each VOC group. The 95th percentile VOC air data were considered to be representative of a chronic, worst case, upper end air concentration. These data were therefore used in the point estimate exposure analysis. Maximum VOC air concentrations were not considered appropriate for use in predicting chronic exposure levels as they are more representative of a short-term fluctuation from the annual average, rather than being indicative of a long term event. The stochastic analysis employed the mean and standard deviation to form a continuous lognormal distribution representing potential VOC air levels. Table E-3.1 outlines the VOC group concentrations used within the existing ambient exposure scenario.

Table E-3.1 VOC Surrogate Group Concentrations Used Within the Existing Ambient Scenario

VOC Group Name	Point Estimate Value (95th percentile) (ug/m^3)	Mean (ug/m^3)	S.D. (ug/m^3)	Distribution Type
Benzene	2.96	1.34	0.82	lognormal
Toluene	9	3.29	6.09	lognormal
Ethylbenzene	1.12	0.43	0.33	lognormal
Xylene	4.68	1.75	1.39	lognormal
Methyl-tert-butyl-ether[1]	0 to 30			uniform
Butadiene	0.66	0.22	0.23	lognormal
Aldehyde group	6.28	3.44	2.59	lognormal

[1] No ambient Saint John air monitoring data were available for Methyl-tert-butyl-ether. However, API (1989) reported an MTBE air concentration of less than or equal to 30 ug/m^3 for areas near oil refineries

Existing Ambient PAH Air Concentrations

Ambient PAH air concentration data were provided by the New Brunswick DOE (1999). Of the three monitoring locations of concern (*i.e.,* Forest Hills, Silver Falls and Champlain Heights), the Forest Hills station was the only location where PAH air monitoring data were available.

The PAH air data provided by NB DOE contained ambient air concentrations for 29 individual PAHs collected on 5 different sampling days from January to December, 1995. These data also included total PAH air concentrations and total suspended particulate (TSP) measured on each sampling day. Although these data were collected in relative close proximity to the refinery, they do not represent refinery PAH emissions in isolation. Rather, as these data are ambient measurements, they represent a number of potential point and mobile sources of PAHs including traffic, other industries, long range transboundary movement, domestic heating activities, barbecues and many others.

Based on these data, individual chemicals of concern were isolated from the list of PAHs provided by New Brunswick DOE (1999) and placed into their surrogate groups. As discussed in detail in Appendix G, each group member was assigned a toxic equivalency factor, relative to their group representative's toxicity. Means, standard deviations and 95th percentile air concentrations were calculated for each PAH group. The 95th percentile PAH air data were considered to be representative of a chronic, worst case, upper end air concentration. These data were therefore used in the point estimate exposure analysis. Maximum PAH air concentrations were not considered appropriate for use in predicting chronic exposure levels as they were considered more representative of a short-term fluctuation from the annual average, rather than being indicative of a long term event. The stochastic analysis employed the mean and standard deviation to form a continuous lognormal distribution representing potential PAH air levels. Table E-3.2 outlines the PAH group concentrations used within the existing ambient exposure scenario.

Table E-3.2 PAH Equivalency Concentrations Used Within the Existing Ambient Scenario at Forest Hills

PAH Surrogate Groups	Point Estimate Value (95th percentile) (ug/m^3)	Mean (ug/m^3)	S.D. (ug/m^3)	Distribution Type
Benzo(a)pyrene [1]	0.000852	0.000595	0.000124	lognormal
Benzo(a)pyrene(s) [2]	0.000225	0.000146	0.0000429	lognormal
Anthracene	0.0000148	0.000013	0.000001	lognormal
Naphthalene	0.00153	0.000794	0.00222	lognormal
Fluorene	0.0146	0.01	0.00222	lognormal

[1] Benzo(a)pyrene group evaluated in the risk assessment using the individual PAH model.

[2] Benzo(a)pyrene group evaluated in the risk assessment using the whole mixture model for PAHs.

Existing Ambient Combustion Gases and Particulate Air Concentrations

Existing ambient air concentrations of combustion gases (*i.e.*, carbon monoxide, sulphur dioxide and nitrogen oxides) and particulate matter (*i.e.*, total suspended particulate, PM_{10}, $PM_{2.5}$) were available for a variety of locations in Saint John. Details of ambient concentrations and monitoring locations of these chemicals / chemical groups can be found in Section 5 of the main report.

E-3.4 Derivation of VOC and PAH Air Concentrations Within the Existing and Future Study Scenarios

In order to predict PAH concentrations associated with current and future stack emission rates, suspended particulate concentrations in air were required. Isopleths describing the distribution of total suspended particulates (TSP) and SO_x in the study area for both current and future rates of stack emissions were generated by Stantec (1999a,b). The modelling was limited, for both the current and future scenarios, to stack emissions from the oil refinery and several other point sources in the Saint John area (Irving Paper, Irving Pulp and Paper, Lantic Sugar, and the Courtney Bay Power Generating Station). In addition, the air modelling did not consider other sources of either particulate material or SO_x that might contribute to the air quality such as urban activity and long range transport.

To predict ambient air concentrations of PAHs under the existing and future study scenarios, it was assumed that these chemicals (*i.e.,* PAHs) were associated with airborne particulate matter; therefore making TSP the primary vehicle for PAHs in air. Isopleth data, as reported by Stantec (1999a), were used to identify the annual average particulate air concentrations associated with current and future stack emission rates at three monitoring locations; Forest Hills, Champlain Heights and Silver Falls. For the current stack emission rates, particulate concentrations in air were determined to be approximately 0.58, 1.73 and 1.01 ug/m^3, at Forest Hills, Champlain Heights and Silver Falls, respectively. For the future stack emission rates, annual average particulate concentrations of 0.73, 2.02 and 1.45 ug/m^3 at Forest Hills, Champlain Heights and Silver Falls, respectively, were reported.

The proportion of TSP comprised of total PAHs can be determined by using the ambient PAH and TSP air monitoring data from the Forest Hills area in Saint John, N.B. These data were provided by New Brunswick DOE (1999). As mentioned in Section E-3.3, this data set contained TSP air concentrations that were measured concurrently with total PAH air concentrations at Forest Hills. However, to determine PAH surrogate group air concentrations (*i.e.,* Benzo (a)pyrene, Benzo(a)pyrene(s), Anthracene, Naphthalene and Fluorene air concentrations) at Forest Hills, Champlain Heights and Silver Falls, Saint John-specific TSP monitoring data and PAH surrogate group concentrations (based on the PAH monitoring data at Forest Hills, N.B.) were used. Specifically, TSP monitoring data and PAH surrogate group air concentrations were used to develop several Saint John-specific ratios, relating TSP to individual PAH surrogate group concentrations. This relationship was derived by calculating the ratio of the mean PAH surrogate group concentration to the mean TSP air concentration, resulting in a ratio which describes the fraction of total ambient TSP comprised of a specific PAH surrogate group. Table E-3.3 presents the Saint John-specific mean PAH surrogate group to mean TSP ratios calculated for the current assessment.

Table E-3.3 Saint John-Specific Mean PAH Surrogate Group Concentrations to Mean TSP Concentrations Measured at Forest Hills, N.B

PAH Surrogate Groups	Mean PAH Surrogate Group Concentration (ug/m^3)	Mean TSP Air Concentration (ug/m^3)	Mean PAH Surrogate to TSP Ratio
Benzo(a)pyrene [1]	0.000595	25.5	0.000023
Benzo(a)pyrene(s) [2]	0.000146	25.5	0.000006
Anthracene	0.000013	25.5	0
Fluorene	0.01	25.5	0.000392
Naphthalene	0.000794	25.5	0.000031

[1] Benzo(a)pyrene group evaluated in the risk assessment using the individual PAH model.

[2] Benzo(a)pyrene group evaluated in the risk assessment using the whole mixture model for PAHs.

These ratios, or fractions were applied to the annual average TSP air concentrations predicted by Stantec (1999a) at Forest Hills, Champlain Heights and Silver Falls, to produce estimated PAH surrogate group concentrations for each location and stack emission scenario. Table E-3.4 outlines the PAH group concentrations used within the existing and future study area scenarios.

Table E-3.4 **Mean PAH Equivalency Concentrations Used Within the Existing and Future Study Area Scenarios**

PAH Surrogate Groups	FOREST HILLS (ug/m^3)	SILVER FALLS (ug/m^3)	CHAMPLAIN HEIGHTS (ug/m^3)
Existing Study Area Scenario			
Benzo(a)pyrene [1]	0.0000135	0.0000236	0.0000404
Benzo(a)pyrene(s) [2]	0.000003	0.000006	0.00001
Anthracene	0	0	0
Naphthalene	0.000018	0.0000315	0.0000539
Fluorene	0.000227	0.000396	0.000679
Future Study Area Scenario			
Benzo(a)pyrene	0.0000169	0.0000338	0.0000471
Benzo(a)pyrene(s)	0.000004	0.000008	0.0000116
Anthracene	0	0	0.000001
Fluorene	0.0000225	0.0000452	0.0000629
Naphthalene	0.000284	0.000569	0.000793

[1] Benzo(a)pyrene group evaluated in the risk assessment using the individual PAH model.

[2] Benzo(a)pyrene group evaluated in the risk assessment using the whole mixture model for PAHs.

For the existing ambient, and the two modelled scenarios *(i.e.,* existing and future), the measured and/or predicted PAH and VOC air concentrations in the Saint John air shed were used to estimate other environmental media concentrations of concern (*i.e.,* soil, dust, and vegetation). The following sections outline the methods and assumptions used to quantify other environmental media concentrations, as well as chemical exposures by selected human receptors and their associated human health impacts.

E-4.0 HUMAN RECEPTOR SELECTION AND CHARACTERISTICS

E-4.1 Receptor Selection

Consideration was given to identifying receptors that would be at the greatest potential risk from the facility emissions, either through having the greatest probability of exposure to chemicals or through having the greatest sensitivity to these chemicals. Female receptors were selected for evaluation as they generally receive higher exposure to chemicals than males when considered on a body weight basis (*e.g.*, mg chemical/kg body weight). If no potential adverse health risks are predicted for the female receptors, then it can be assumed that less sensitive receptors receiving lower chemical exposures (*e.g.*, male receptors) also would not be at risk. For chemicals considered to be of potential concern, a range of female hypothetical receptor types were evaluated in the existing ambient, existing study area, future study area and background scenarios, as follows:

- infant (0 to 6 months of age);
- preschool child or toddler (7 months to 4 years);
- child (5 to 11 years);
- adolescent (12 to 19 years); and
- adult (>20 years)

(Source: O'Connor Associates and Richardson, 1997).

In order to conservatively assess potential incremental lifetime cancer risks to carcinogenic chemicals, a lifetime or composite female receptor was also considered for the current risk assessment. The composite receptor incorporates all receptor lifestages (*i.e.*, infant, preschool child, child, adolescent and adult) from birth to 70 years of age. The 70 year lifetime is the assumed lifespan for humans, is a conservative number used in many risk assessments and is an accepted default value (US EPA, 1989). IRIS also makes a 70 year assumption in the derivation of slope factors. The EPA activity factors (US EPA, 1997) indicates that this default value of 70 years could be altered to use a more realistic estimate of exposure duration data based on real lifetime data or data regarding how long people typically work or live in one place.

The characteristics of each female receptor type are outlined in the following tables. Receptor characteristics were based on the data for Canadian populations provided by O'Connor Associates (1997), as well as other published literature sources.

E-4.2 Female Receptor Characteristics

Table E-4.1 Female Nursing Infant Receptor (0 to 6 months of age)

Receptor Parameter	Point Estimate	Mean	S.D.	Minimum	Maximum	Distribution Type	Reference
Body Weight (kg)	8.2	8.2	2.9			lognormal	O'Connor Associates, 1997
Fraction of Exposed Skin (Summer)	0.578						Anderson, 1985 , U.S. EPA, 1997
Fraction of Exposed Skin (Winter)	0.235						Anderson, 1985, in U.S. EPA, 1997
Surface Area of Hands (m^2)	0.032	0.032	0.003			lognormal	O'Connor Associates, 1997
Whole Body Surface Area (m^2)	0.351	0.351	0.048			lognormal	O'Connor Associates, 1997
Soil Adherence Factor ($g/m^2/d$)	10	5.85		1.7	10	uniform	U.S. EPA, 1992
Amount of Soil/Dust Ingested (g/d)	0.035	0.035					CEPA, 1992
Amount of Air Inhaled (m^3/d)	3.2	2.1	0.6			lognormal	O'Connor Associates, 1997
Fraction of Produce from Home Garden	0.3	0.3					Assumed
Amount of Root Vegetables Consumed (g/d)	192	83	58			lognormal	O'Connor Associates, 1997
Amount of Other Vegetables Consumed (g/d)	181	72	59			lognormal	O'Connor Associates, 1997
Amount of Fruit and Juices Consumed (g/d)	328	136	96			lognormal	O'Connor Associates, 1997
Time Spent Outside (hr/d)	6						U.S. EPA, 1997
Time Spent Inside (hr/d)	18						U.S. EPA, 1997

Table E-4.2 Female Preschool Child Receptor (7 months to 4 years of age)

Receptor Parameter	Point Estimate	Mean	S.D.	Minimum	Maximum	Distribution Type	Reference
Body Weight (kg)	16.4	16.4	4.5			lognormal	O'Connor Associates, 1997
Fraction of Exposed Skin Summer (m^2)	0.5798						Anderson, 1985 &U.S. EPA, 1997
Fraction of Exposed Skin Winter	0.2048						Anderson, 1985 &U.S. EPA, 1997
Surface Area of Hands (m^2)	0.043	0.043	0.005			lognormal	O'Connor Associates, 1997
Whole Body Surface Area (m^2)	0.797	0.605	0.108			lognormal	O'Connor Associates, 1997
Soil Adherence Factor ($g/m^2/d$)	10	5.85		1.7	10	uniform	U.S. EPA, 1992
Amount of Soil/Dust Ingested (g/d)	1.3	0.091	0.126	0.00218		lognormal	Thompson and Burmaster, 1991
Amount of Air Inhaled (m^3/d)	13.19	8.8	2.4			lognormal	O'Connor Associates, 1997
Fraction of Produce from Home Garden	0.3	0.3		0			Assumed
Amount of Root Vegetables Consumed (g/d)	264	99	91			lognormal	O'Connor Associates, 1997
Amount of Fruit and Juices Consumed (g/d)	606	234	191			lognormal	O'Connor Associates, 1997
Amount of Other Vegetables Consumed (g/d)	195	67	74			lognormal	O'Connor Associates, 1997
Time Spent Outside (hr/d)	6						U.S. EPA, 1997
Time Spent Inside (hr/d)	18						U.S. EPA, 1997

Table E-4.3 Female Child Receptor (5 years to 11 years of age)

Receptor Parameter	Point Estimate	Mean	S.D.	Minimum	Maximum	Distribution Type	Reference
Body Weight (kg)	33.6	33.6	9.3			lognormal	O'Connor Associates, 1997
Fraction of Exposed Skin Summer	0.5815						Anderson, 1985 &U.S. EPA, 1997
Fraction of Exposed Skin Winter	0.1755						Anderson, 1985 &U.S. EPA, 1997
Surface Area of Hands (m^2)	0.059	0.059	0.008			lognormal	O'Connor Associates, 1997
Whole Body Surface Area (m^2)	1.015	1.015	0.203			lognormal	O'Connor Associates, 1997
Soil Adherence Factor ($g/m^2/d$)	10	5.85		1.7	10	uniform	U.S. EPA, 1992
Amount of Soil/Dust Ingested (g/d)	1.3	0.091	0.126	0.00218		lognormal	Thompson and Burmaster, 1991
Amount of Air Inhaled (m^3/d)	19.4	14	3			lognormal	O'Connor Associates, 1997
Fraction of Produce from Home Garden	0.3	0.3		0			Assumed
Amount of Root Vegetables Consumed (g/d)	385	143	134			lognormal	O'Connor Associates, 1997
Amount of Fruits and Juices Consumed (g/d)	722	252	235			lognormal	O'Connor Associates, 1997
Amount Other Vegetables Consumed (g/d)	288	98	110			lognormal	O'Connor Associates, 1997
Time Spent Outside (hr/d)	6						U.S. EPA, 1997
Time Spent Inside (hr/d)	18						U.S. EPA, 1997

Table E-4.4 **Female Adolescent Receptor (12 years to 19 years of age)**

Receptor Parameter	Point Estimate	Mean	S.D.	Minimum	Maximum	Distribution Type	Reference
Body Weight (kg)	56.2	56.2	10.2			lognormal	O'Connor Associates, 1997
Fraction of Exposed Skin Summer	0.578						Anderson, 1985 &U.S. EPA, 1997
Fraction of Exposed Skin Winter	0.13						Anderson, 1985 &U.S. EPA, 1997
Surface Area of Hands (m^2)[a]	0.076	0.076	0.007			lognormal	O'Connor Associates, 1997
Whole Body Surface Area (m^2)[a]	1.505	1.505	0.181			lognormal	O'Connor Associates, 1997
Soil Adherence Factor ($g/m^2/d$)	10	5.85		1.7	10	uniform	U.S. EPA, 1992
Amount of Soil/Dust Ingested (g/d)	0.1			0.001	0.1	uniform	LaGoy, 1987; Calabrese *et al.*, 1987
Amount of Air Inhaled (m^3/d)[a]	19.2	14	2.9			lognormal	O'Connor Associates, 1997
Fraction of Produce from Home Garden	0.3	0.3		0			Assumed
Amount of Root Vegetables Consumed (g/d)	462	190	146			lognormal	O'Connor Associates, 1997
Amount of Fruits and Juices Consumed (g/d)	732	258	237			lognormal	O'Connor Associates, 1997
Amount of Other Vegetables Consumed (g/d)	354	120	136			lognormal	O'Connor Associates, 1997
Time Spent Outside (hr/d)	1.5						U.S. EPA, 1997
Time Spent Inside (hr/d)	21						U.S. EPA, 1997

[a] Data reported from age group 9-11yrs, (O'Connor Associates, 1997).

Table E-4.5 **Female Adult Receptor (20 years of age and greater)**

Receptor Parameter	Point Estimate	Mean	S.D.	Minimum	Maximum	Distribution Type	Reference
Body Weight (kg)	63.1	63.1	11.8			lognormal	O'Connor Associates, 1997
Fraction of Exposed Skin Summer	0.578						Anderson, 1985 &U.S. EPA, 1997
Fraction of Exposed Skin Winter	0.122						Anderson, 1985 &U.S. EPA, 1997
Surface Area of Hands (m^2)	0.083	0.083	0.007			lognormal	O'Connor Associates, 1997
Whole Body Surface Area (m^2)	1.99	1.675	0.184			lognormal	O'Connor Associates, 1997
Soil Adherence Factor ($g/m^2/d$)	10	5.85		1.7	10	uniform	U.S. EPA, 1992
Amount of Soil/Dust Ingested (g/d)	0.1			0.001	0.1	uniform	LaGoy, 1987; Calabrese *et al.*, 1987
Amount of Air Inhaled (m^3/d)	14.4	14.4	3.1			lognormal	O'Connor Associates, 1997
Fraction of Produce from Home Garden	0.3	0.3		0			Assumed
Amount of Root Vegetables Consumed (g/d)	387	157	124			lognormal	O'Connor Associates, 1997
Amount of Fruit and Juices Consumed (g/d)	649	245	202			lognormal	O'Connor Associates, 1997
Amount of Other Vegetables Consumed (g/d)	345	129	119			lognormal	O'Connor Associates, 1997
Time Spent Outside (hr/d)		1.5					U.S. EPA, 1997
Time Spent Inside (hr/d)		21					U.S. EPA, 1997

E-5.0 HUMAN EXPOSURE PATHWAYS AND CONSERVATIVE ASSUMPTIONS USED IN THE ASSESSMENT

For the Public Health Risk Assessment, a residential situation involving all the female life stages was examined under a variety of exposure conditions (scenarios). With respect to carcinogenic chemicals, all female life stages were assessed in order to generate a composite carcinogenic risk estimate. The exposure pathways considered were those typically associated with a residential situation and are outlined in Table E-5.1. Human female receptors were conservatively assumed to spend 100 percent of their time on-site while consuming 30% of their daily dietary requirement of fruits and vegetables from the immediate area.

Table E-5.1 Exposure Pathways and Assumptions Related to the Irving Site

Criteria	Residential
Receptors	Female (0 to 70 years of age) - infant (0 to < 6 months of age) - preschooler (6 months to < 5 years of age) - child (5 to < 12 years of age) - adolescent (12to < 20 years of age) - adult (> 20 years of age)
Pathways	Direct Air Inhalation (particulate and vapour phase) - outdoor air inhalation - indoor air inhalation
	Dermal Contact with Air - outdoor air - indoor air
	Soil/dust (indoor/outdoor) - inhalation of resuspended soil/dust - incidental ingestion of soil/dust - dermal contact
	Plant - ingestion of home garden produce (leafy vegetables and produce/fruits)
	Drinking Water - ingestion of water
Assumptions	- 30% of the vegetable and fruit eaten was assumed to come from local home gardens
	- 3 months of winter, 9 months of summer
	- 24 hours/day, 7 days/ week, 52 weeks/year, 50 years assumed spent at the residence

E-6.0 EQUATIONS AND ALGORITHMS USED TO ESTIMATE EXPOSURES

This section provides the equations and algorithms that were used to estimate the potential health risks to female receptors based upon typical background exposures and those related to facility emissions. The primary focus of the following sections is to provide a worked example illustrating the methods, assumptions and formula used to predict quantitative estimates of exposure and related human health risks.

The following worked example uses a residential situation involving a female preschool child (toddler) residing at Forest Hills, New Brunswick, while being exposed to benzene-impacted air. Similar methods were used to evaluate all receptors and chemicals of concern in the vicinity of the Irving Oil Refinery.

E-6.1 Estimation of Soil Concentrations

Estimating soil concentrations from air monitoring and dispersion data is one of the initial steps towards predicting other environmental media concentrations. In order to predict soil concentrations, deposition rates or air concentrations and deposition velocities are required. The following method used to derive soil concentrations, given the corresponding wet and dry chemical deposition rates ($\mu g/m^2/day$) is based, in part, on the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustion Emissions (U.S. EPA, 1990).

The following illustrates the methodology used to derive soil concentrations ($\mu g/g$) given the corresponding benzene air concentrations in ($\mu g/m^3$) within the Forest Hill area (U.S. EPA, 1993). Based on communication with Stantec, only wet deposition was considered for VOCs, while both wet and dry deposition rates were considered for PAHs.

For chemicals considered to degrade (*eg.*, benzene), the following equation is used:

$$csoil(\mu g / g) = \frac{cair(\mu g / m^3) \times tdv(m / s) \times opdays \times adjst(s / day) \times \left(1 - e^{-kt}\right)}{ssvr(m^3 / m^2) \times \rho_{Soil}(g / m^3) \times k}$$

where:

csoil = soil concentration at any time t ($\mu g/g$)

cair = air concentrations ($2.96\ \mu g/m^3$)

tdv = total deposition velocity (wet deposition velocity only = 0.005 m/s)

opdays = number of operating days (number of summer plus number of winter operating days = 365 days)

adjst = number of seconds per day (86400 sec./day)

t = number of operating years (30 years)

k = elimination rate constant ($\ln 2/t_{1/2}$; years^{-1})

$t_{1/2}$ = chemical half-life in soil (16day, 0.044 years)

ssvr = soil volume per area ratio ($0.05 m^3/m^2$)

ρ_{soil} = soil bulk density ($1.95e+05\ g/m^3$)

For the current assessment, the soil concentration for benzene after 30 years of deposition was estimated to be 3.04 $\mu g/g$.

E-6.2 Estimation of Exposure via Home Grown Produce

The uptake of chemicals into vegetation (*e.g.*, fruits, vegetables, grasses) is a topic that has been extensively reviewed in the literature, since this pathway is a potential source when vegetation is consumed by human and ecological receptors. Chemicals are taken up into vegetation from three principle sources: particulates in air (*e.g.*, dust, or aerosols); vapours in air (*e.g.*, gases); and, subsurface compartments (*e.g.*, soil, water) (Rolfe, 1972; Baes, 1982; Travis and Hattemer-Frey, 1988; Boon and Sultanpour, 1992; Muller *et al.*, 1993; Schroll and Scheunert, 1993; McCrady and Maggard, 1993). The magnitude of uptake from these sources has been correlated with physical/chemical parameters (*e.g.*, vapour pressure, octanol water partition coefficient, *etc.*), with soil parameters (*e.g.*, fraction of organic carbon, soil moisture, clay content, *etc.*), with plant parameters (*e.g.*, lipid content, moisture content, *etc.*) and with chemical concentrations in the principle sources listed above.

The methodology used to estimate the contribution from each route of chemical uptake in vegetation (*i.e.*, home garden vegetables) and the resulting exposure to human receptors as a result of consumption are described in the following sections.

E-6.2.1 Root Uptake

A substantial amount of empirical data is available in the literature that demonstrates there is significant uptake of organics into plants. Organic chemicals in soils are reported to be taken up by vegetation (*i.e.*, carrots, tomatoes, potatoes, narcissus) through the roots (Iwata and Gunther, 1976; Cocucci *et al.*, 1979; Bacci and Gaggi, 1985; Travis and Arms, 1988; Schroll and Scheunert, 1993). Travis and Arms (1988) reported that uptake of organic chemicals by vegetation is correlated to octanol-water partition coefficients (K_{OW}).

The method of Travis and Arms (1988), as modified by Travis and Blaylock (1992), is used to estimate the bioconcentration of organic chemicals from the soil to vegetation *via* root uptake. This method is based on measured data which demonstrated that the bioconcentration factor for an organic chemical in vegetation is inversely proportional to the square root of the octanol-water partition coefficient (K_{ow}). Root uptake of organics has been correlated with K_{ow} and has been shown to decrease as K_{ow} increases (Briggs *et al.*,1982; in Travis and Blaylock, 1992). A geometric mean regression analysis of data for 29 different organic chemicals demonstrated a relationship between bioconcentration factors in vegetation and octanol-water partition coefficients (r= 0.73) (Travis and Arms, 1988). The first step of the method of Travis and Arms (1988), as modified by Travis and Blaylock (1992), is to calculate a chemical-specific bioconcentration factor for vegetation. The bioconcentration factor for vegetation (BVR) is defined as the ratio of the concentration in the plant (μg of chemical/g of dry plant) to the concentration of the chemical in the soil (μg of chemical/g of dry soil). The BVR can be calculated for organic chemicals according to the formula:

Bioconcentration Factor

$$BVR = 38.73\ K_{OW}^{\ -0.578}$$

where:

BVR = bioconcentration factor for vegetation *via* root uptake (μg/g dry plant / μg/g dry soil)

K_{ow} = octanol-water partition coefficient (Benzene, 134.9 unit-less).

Therefore the benzene bioconcentration factor for vegetation via *root uptake was estimated at 2.27.*

Several studies have indicated that inorganic metals are taken up into plants through the roots (Baes, 1982). Bioconcentration values for plants *via* the roots (BVR) for inorganic chemicals are based on measured values from the study by Baes (1982).

The concentration of benzene in vegetation due to root uptake was then estimated according to the following formula:

$$CVR = CS \times BVR \times FVD$$

where:

CVR = concentration of chemical in the plant due to root uptake (μg/g)

CS = concentration of the chemical in the soil (3.04 μg/g)

BVR = bioconcentration factor for vegetation due to root uptake (2.27 unitless)

FVD = fraction of the fruit or vegetable that is dry matter (assumed to be 0.115 for fruits and vegetables)

The concentration of benzene in vegetation due to root uptake was estimated to be 0.79 μg/g.

It is reasonable to assume that food preparation practices such as washing, peeling and/or cooking will likely reduce edible vegetation concentrations relative to those predicted or directly measured in the field. Based on work by Wipf, Homberger, Neuner, Ranalder, Vetter and Vuilleumier (1982), the U.S. EPA (1994) identified processes such as peeling, cooking and cleaning that would reduce vegetable concentrations. Using professional judgement, CANTOX ENVIRONMENTAL INC. has incorporated a factor of 35%, which represents the amount of chemical remaining after washing and peeling.

Benzene exposure estimates to a female toddler from the consumption of fruits and vegetables contaminated *via* root uptake was then estimated using the following equation.

$$\text{EVR (ug/kg/day)} = \frac{\text{CVR (ug/g)} \times \text{AVC (g/d)} \times \text{WP} \times \text{AF}_{\text{oral}} \times \text{FHP}}{\text{BW (kg)}}$$

where:
EVR = daily exposure from vegetation per day due to root uptake (μg/kg/day)
CVR = concentration of the chemical in the plant due to root uptake (0.79 μg/g)
AVC = amount of vegetation consumed per day (1065 g/day)
AF_{oral} = oral bioavailability of compound (97%)
FHP = fraction of vegetation that is from home garden (0.3)
BW = body weight (16.4 kg)
WP = washing and peeling factor of 35%.

According to the above equation and input parameters, the daily benzene exposure from consumption of vegetation due to root uptake was estimated to be 5.23 μg/kg/day (adjusted for bioavailability).

E-6.2.2 Atmospheric Deposition

The contribution of atmospheric deposition of particulate onto outer plant surfaces was estimated using the formula presented by Travis et al., (1986) seen below. Atmospheric deposition was only considered for plants whose edible portions are above the ground (*i.e.,*potatoes, onions and carrots were not included). Furthermore, the human produce available for deposition were grouped into two categories: leafy vegetables (*e.g.,* lettuce, cabbage, broccoli and spinach) and exposed produce (*e.g.,* non-citrus fruits and tomatoes).

The first step in calculating the concentrations of chemicals on plants due to deposition was to estimate the intercept fraction for the various crop types. Baes *et al.* (1984) of the (U.S.) Department of Energy estimated mean intercept fractions for leafy crops and exposed produce using an approach which involved a weighted approach using consumption patterns. Baes *et al.* (1984) determined a mean intercept fraction (r) of 0.15 for leafy crops and 0.052 for exposed produce. The crop yield for leafy crops was assumed to equal 8.6 kg/m^2 (that reported for lettuce by Stevens and Gerbec, 1988) and the crop yield for exposed produce was assumed to equal 12.0 kg/m^2 (that reported for tomatoes by Stevens and Gerbec, 1988).

Based on communication with Stantec, only wet deposition was considered for VOCs. For PAHs both wet and dry deposition was considered.

The total deposition multiplier was estimated by the following equation:

Deposition Multiplier

$$DDM = \frac{\left(depmdp + depmdv + depmwp + depmwv\right) \times LGS}{dpy}$$

where:

DDM = total deposition multiplier (m/day)

depmdp = dry particulate multiplier (cppf (0.0010);unitless) x cdvd (0 m/s)

depmwp = wet particulate multiplier (cppf (0.0010);unitless) x cdvw (0.005m/s) x 0.10

depmdv = dry vapour phase multiplier (cvpf (0.99);unitless) x cdvd (0 m/s)

depmwv = wet vapour phase multiplier (cvpf (0.99);unitless) x cdvw (0.005 m/s) x 0.10

Consistent with the methodology provided by the U.S. EPA (1993), when considering deposition onto plants, chemicals with a $K_{ow} < 1000$ should have a 10% adhesion factor applied to the wet deposition. This accounts for chemicals with a low K_{ow} which do not adhere to plants in the same fashion as chemicals with a high K_{ow}.

LGS = length of growing season (7884000 seconds/year)

dpy = days per year (365 days/year)

From the above equation and input parameters the total deposition multipliers for benzene were, 10.7 m/day.

The concentration in the leafy crops or exposed produce was then calculated using the formula:

$$\text{CVD (ug/g)} = \frac{\text{cair (ug/m}^3\text{)} \times \text{DDM (m/day)} \times \text{WP} \times \text{r} \times \text{UCF (kg/g)}}{\text{Y (kg/m}^2\text{)} \times \text{K (d}^{-1}\text{)}}$$

where:

CVD = concentration of the chemical in the plant due to deposition of particulates (μg/g)

cair = concentration of the chemical in the air (benzene, 2.96 μg/m^3)

DDM = total deposition multiplier previously calculated (10.7 m/day)

WP = washing peeling factor (0.35; assumed)

K = ln(2)/weathering half-life of particulates on outer plant surfaces (based on Stevens and Gerbec (1988) the weathering half-life was assumed to be 14 days for all particulates) (*i.e.*, k= ln(2)/14 days= 0.0495 days^{-1})

r = intercept fraction (0.15 for leafy crops and 0.052 for exposed produce; Baes et al., 1984)

Y = annual crop yield (8.6 kg/m^2 for leafy crops and 12 kg/m^2 for exposed produce; Stevens and Gerbec, 1988)

UCF = 1 kg / 1,000 g

According to the above equation and input parameters, the concentration of benzene in vegetation due to deposition of particulate was estimated to be 0.004 and 0.00097 μg/g for leafy crops and exposed produce, respectively.

As stated above, atmospheric deposition could only occur on plants with edible portions that are above ground. The chemical exposure to persons from leafy crops and exposed produce was estimated using the following equation:

$$EVD_{DEP}(\mu g/kg/day) = \frac{\left(CVD_{leafy}(\mu g/g) \times AVC_{leafy}(g/d)\right) + \left(CVD_{exposed}(\mu g/g) \times AVC_{exposed}(g/d)\right) \times AF_{oral} \times FHP}{BW(kg)}$$

where:

EVD_{DEP} = daily exposure from vegetation per day due to particulate deposition (μg/kg/day)

CVD_{leafy} = concentration of the chemical in leafy crops due to deposition of particulates (0.004 μg/g)

$CVD_{exposed}$ = concentration of the chemical in exposed produce due to deposition of particulates (0.00097 μg/g)

AVC_{leafy} = amount of leafy vegetation consumed per day (195 g/day)

$AVC_{exposed}$ = amount of exposed produce consumed per day (606 g/day)

AF_{oral} = oral bioavailability of compound (97%)

FHP = fraction of vegetation that is from home garden (0.3)

BW = body weight (16.4 kg)

According to the above equation and input parameters, benzene exposure from the consumption of home grown produce impacted via deposition of particulate on both leafy crops and exposed produce was estimated to be 2.4e-02 μg/kg/day (adjusted for bioavailability).

E-6.2.3 Soil/Dust Resuspension and Deposition

The potential for dust, derived from chemically impacted soil, to resuspend and deposit onto vegetative surfaces does exist. Although this pathway is not expected to be a major contributor to the overall chemical concentrations in vegetation, it was assessed in order to maintain a complete and consistent approach. The following equation estimates the contribution to the final chemical plant concentration *via* the resuspension mechanism. The concentration in leafy crops and exposed produce due to soil resuspension is estimated using the formula shown below.

$$\text{CVD (ug/g)} = \frac{\text{csoil (ug/g)} \times \text{dfs} \times \text{sodl (g/m}^3\text{)} \times \text{DDM (m/day)} \times \text{WP} \times \text{r} \times \text{UCF (kg/g)}}{\text{Y (kg/m}^2\text{)} \times \text{K (d}^{-1}\text{)}}$$

where:

CVD = concentration of the chemical in the plant due to soil/dust resuspension and deposition of particulates (μg/g)

csoil = concentration of the chemical in the soil (3.04 μg/g)

dfs = fraction of outside dust derived from soil (0.50)

sodl = Summer outside dust concentration (0.000042 g/m^3)

DDM = total deposition multiplier previously calculated, (10.7)

WP = washing peeling factor (0.35; assumed)

K = ln(2)/weathering half-life of particulates on outer plant surfaces (based on Stevens and Gerbec (1988) the weathering half-life was assumed to be 14 days for all particulates) (*i.e.*, k= ln(2)/14 days= 0.0495 days^{-1})

r = intercept fraction (0.15 for leafy crops and 0.052 for exposed produce; Baes et al., 1984)

Y = annual crop yield (8.6 kg/m^2 for leafy crops and 12 kg/m^2 for exposed produce; Stevens and Gerbec, 1988)

UCF = 1 kg / 1,000 g

Thus, according to the above equation and input parameters, the concentration of benzene in vegetation due to resuspension and deposition of particulate was estimated to be 0.000000084 and 0.00000002 μg/g, for leafy crops and exposed produce, respectively.

As stated above, soil/dust resuspension could only occur on plants with edible portions that are above ground. The chemical exposure to persons from leafy crops and exposed produce was estimated using the following equation.

$$EVD_{RESDEP}(\mu g/kg/day) = \frac{\left[CVD_{leafy}(\mu g/g) \times AVC_{leafy}(g/d) + CVD_{exposed}(\mu g/g) \times AVC_{exposed}(g/d)\right] \times AF_{oral} \times FHP}{BW(kg)}$$

where:

EVD_{RESDEP} = daily exposure from vegetation per day due to soil/dust resuspension and deposition (μg/kg/day)

CVD_{leafy} = concentration of the chemical in leafy crops due to deposition of particulate (0.000000084 μg/g)

$CVD_{exposed}$ = concentration of the chemical in exposed produce due to deposition of particulate (0.00000002 μg/g)

AVC_{leafy} = amount of leafy vegetation consumed per day (195 g/day)

$AVC_{exposed}$ = amount of exposed produce consumed per day (606 g/day)

AF_{oral} = oral bioavailability of compound (97%)

FHP = fraction of vegetation that is from home garden (0.3)

BW = body weight (16.4 kg)

According to the above equation and input parameters, the exposure to benzene from the consumption of vegetation impacted by resuspension and deposition of particulate on both leafy crops and exposed produce was estimated to be 0.00000051 μg/kg/day (adjusted for bioavailability).

E-6.2.4 Air-to-Plant Transfer of Vapor Phase Chemicals

This final pathway by which plants may accumulate chemicals *via* air-to-plant transfer of vapours is estimated by calculating a vapour phase transfer coefficient for volatile organic chemicals. The following equation has been derived by a regression equation provided by Bacci, *et al.* (1992). The transfer factor has been adjusted from a volumetric air-to-leaf biotransfer relationship, to one which relates leaf concentrations on a mass basis to air concentrations on a volumetric basis.

$$BVT = 0.022 \times K_{ow} \Big/ \Big(H\,(Pa\ m^3/mol)/T(K)/8.314(Pa\ m^3/mol)\Big) \Big/ 1000/800(kg/m^3)$$

BVT = biotransfer coefficient (μg/g/ μg/m^3)
K_{ow} = octanol-water partition coefficient (134.9 unitless)
H = Henry's Law constant for the compound (557 Pa m^3/mol)
800 = density of plant matter (kg/m^3)
1000 = conversion factor (g/kg)
T = room temperature in Kelvins (283 K)
8.314 = gas constant (Pa m^3/K mol)

Thus according to the above equation and input parameters, the bioconcentration vapour transfer coefficient for benzene was estimated to be 0.0000157 μ*g/g/* μg/m^3.

The daily exposure to benzene from vegetation due to vapour phase transfer was then calculated using the following formula.

$$EVV = \Big(asite(\mu g/m^3) \times cvpf + svho(\mu g/m^3)\Big) \times BVT\,(\mu g/g/\mu g/g) \times \Big(AVC_{leafy} + AVC_{exposed}\Big) \times FHP \times WP \times AF_{oral} / BW\,(kg)$$

where:
EVV = daily exposure from vegetation per day due to vapor phase transfer (μg/kg/day)
asite = concentration of the chemical in the air (2.96 μg/m^3)
cvpf = chemical vapor phase fraction (0.99 unitless)
svho = chemical concentration in air derived from soil at home (0.017 μg/m^3)
BVT = bioconcentration vapour transfer coefficient (0.0000157 μg/g/ μg/m^3)
WP = washing and peeling factor of 35%.
AVC_{leafy} = amount of leafy vegetation consumed per day (195 g/day)
$AVC_{exposed}$ = amount of exposed produce consumed per day (606 g/day)
AF_{oral} = oral bioavailability of compound (97%)
FHP = fraction of vegetation that is from home garden (0.3)
BW = body weight (16.4kg)

According to the above equation and input parameters, the daily benzene exposure to a female *preschool child from the consumption of vegetation impacted by vapor phase transfer was estimated to be 0.00023 μg/kg/day.*

E-6.2.5 Total Exposure from Consumption of Home Grown Produce

The daily exposure to benzene from eating site-grown produce was then calculated using the formula shown below.

$$EXP_{TCV} = EVR + EVD_{DEP} + EVD_{RESDEP} + EVV$$

where:

EXP_{TCV} = total exposure to humans from consuming site-grown vegetation (μg/kg/day)

EVR = daily exposure from vegetation per day due to root uptake (5.23),

EVD_{DEP} = daily exposure from vegetation per day due to particulate deposition (0.024)

EVD_{RESDEP} = daily exposure from vegetation per day due to particulate resuspension and deposition (0.00000051)

EVV = daily exposure to chemical from vegetation due to vapor phase transfer (0.00023 μg/kg/day)

The total benzene exposure as a result of home grown produce consumption was estimated to be 5.24 μg/kg/day (adjusted for bioavailability).

E-6.3 Exposure through the ingestion of Drinking water

Contribution from Drinking water:

$$EXP_{DW}\ (\mu g/kg/day) = \frac{R_{WAT}\ (L/d) \times C_{WAT}\ (\mu g/L) \times AF_{oral}}{BW\ (kg)}$$

where:

EXP_{DW} = oral exposure to chemical from ingestion of drinking water (μg/kg/day)

R_{WAT} = amount of drinking water ingested (1.35 L/day)

C_{WAT} = concentration of chemical in drinking water (0.5 ug/L)

AF_{oral} = fraction of chemical absorbed by receptor by ingestion of water (0.97)

BW = receptor body weight (16.4 kg)

According to the above equation and input parameters, the exposure to benzene from drinking water was estimated to be 0.04 μg/kg/day (adjusted for bioavailability).

E-6.4 Estimation of Exposure from Air

E-6.4.1 Dermal Contact

Dermal Exposure on Outdoor days

$$AirDerm_{outdoor}(\mu g / kg / day) = \frac{cdpcvap(m / hour) \times cair(\mu g / m^3) \times SA(m^2) \times cvpf \times hpd(hr / day) \times \left(rSAS(days / yr) + rSAW(days / yr\right)}{BW(kg) \times DPY(days / yr)}$$

where:

$AirDerm_{outdoor}$ = Dermal Exposure from chemicals in the air during outdoor days (μg/kg/day)
cdpcvap = Dermal permeability constant for vapour phase (0.00206 m/hour)
cair = Site air concentration (2.96 $\mu g/m^3$)
SA = receptor whole body surface area(0.797 m^2)
cvpf = chemical vapor phase fraction (0.99 unitless)
hpd = hours/day (24 hr/day)
rSAS = outdoor summer days spent (68 days/year)
rSAW = outdoor winter days spent (22.8 days/year)
BW = receptor body weight (16.4 kg)
DPY = days per year (365 days/year)

Thus according to the above equation and input parameters the dermal exposure in the air from benzene during outdoor days was estimated to be 0.00175 μg/kg/day.

Dermal Exposure on Indoor days

$$AirDerm_{indoor}(\mu g / kg / day) = \frac{cdpcvap(m / hour) \times cair(\mu g / m^3) \times SA(m^2) \times cvpf \times hpd(hr / day) \times \left(rSPS(days / yr) + rSPW(days / yr\right) \times Inf}{BW(kg) \times DPY(days / yr)}$$

where:

$AirDerm_{indoor}$ = Dermal Exposure from chemicals in the air during indoor days (μg/kg/day)
cdpcvap = Dermal permeability constant for vapour phase (0.00206 m/hour)
cair = Site air concentration (2.96 $\mu g/m^3$)
SA = receptor whole body surface area(0.797 m^2)
cvpf = chemical vapor phase fraction (0.99 unitless)
hpd = hours/day (24 hr/day)
rSPS = indoor summer days spent (206 days/year)
rSPW = indoor winter days spent (68 days/year)

Inf = fraction of indoor air that is from outdoor air (0.75)
BW = receptor body weight (16.4 kg)
DPY = days per year (365 days/year)

Thus according to the above equation and input parameters the dermal exposure in the air to benzene during indoor days was estimated to be 0.0040 μg/kg/day.

E-6.4.2 Direct Air Inhalation

Direct Air Inhalation Exposure on Outdoor days

$$AirInh_{outdoor}(\mu g/kg/day) = \frac{AIAct(m^3/day) \times AF_{Inh} \times cair(\mu g/m^3) \times \left(rSAS(days/yr) + rSAW(days/yr)\right)}{BW(kg) \times DPY(days/yr)}$$

where:

$AirInh_{outdoor}$ = inhalation exposure from chemicals in the air during outdoor days (μg/kg/day)
AIAct = amount of air inhaled on outdoor days (13.19 m^3/day)
cair = site air concentration (2.96 μg/m^3)
AF_{Inh} = inhalation bioavailability of the compound (0.79)
rSAS = outdoor summer days spent (68, days/year)
rSAW = outdoor winter days spent (22.8, days/year)
BW = receptor body weight (16.4 kg)
DPY = days per year (365 days/year)

According to the above equation and input parameters, inhalation exposure to benzene during outdoor days was estimated to be 0.47 μg/kg/day.

Inhalation Exposure Calculations on Indoor days

$$AirInh_{indoor}(\mu g/kg/day) = \frac{AIPass(m^3/day) \times AF_{Inh} \times cair(\mu g/m^3) \times \left(rSPS(days/yr) + rSPW(days/yr)\right) \times Inf}{BW(kg) \times DPY(days/yr)}$$

where :

$AirInh_{Indoor}$ = inhalation exposure from chemicals in the air during indoor day(μg/kg/day)
AIPass = amount of air inhaled on indoor days (13.19 m^3/day)
AF_{Inh} = inhalation bioavailability of the compound (0.79)
cair = site air concentration (2.96 μg/m^3)
rSPS = indoor summer days spent (206 days/year)
rSPW = indoor winter days spent (68 days/year)
Inf = fraction of indoor air that is from outdoor air (0.75)
BW = receptor body weight (16.4 kg)
DPY = days per year (365 days/year)

The benzene exposure via inhalation during indoor days was estimated to be 1.06 μg/kg/day.

E-6.4.3 Total Inhalation and Dermal Exposure from Chemicals in Air

$$Air_{Total} = AirDerm_{indoor} + AirDerm_{outdoor} + AirInh_{indoor} + AirInh_{outdoor}$$

where:

Air_{Total} = Total Inhalation and Dermal Exposure from Chemicals in Air (μg/kg/day)

$AirDerm_{outdoor}$ = Dermal Exposure from chemicals in the air during outdoor days (0.00175 μg/kg/day)

$AirDerm_{Indoor}$ = Dermal Exposure from chemicals in the air during indoor days (0.004 μg/kg/day)

$AirInh_{outdoor}$ = Inhalation Exposure from chemicals in the air during outdoor days (0.47 μg/kg/day)

$AirInh_{Indoor}$ = Inhalation Exposure from chemicals in the air during indoor day (1.06 μg/kg/day)

The total benzene exposure via inhalation and dermal contact with impacted air was estimated to be 1.54 μg/kg/day (adjusted for bioavailability).

E-6.5 Calculation of Exposure from Soil/Dust

E-6.5.1 Assumptions Defining Dust Levels Generated by Soils

Background outside dust levels:	42 μg/m³ (MOEE, 1994)
Percent of dust produced from soil:	50% (Hawley, 1985)
Percent of outside dust level indoors:	75% (Roberts *et al.*, 1974)

Sample calculation concerning the level of dust generated from soil alone (*i.e.*, background levels), suspended in air:

outside: $42\ \mu g/m^3 \times 0.50 / 1{,}000{,}000\ \mu g/g = 0.000021\ g/m^3$
indoors: $42\ \mu g/m^3 \times 0.50 \times 0.75 / 1{,}000{,}000\ \mu g/g = 0.0000157\ g/m^3$

The exposure contributions of benzene from chemically impacted soil were considered for three routes of exposure: i) inhalation of resuspended dusts, ii) incidental ingestion of soil, and iii) dermal contact with skin.

E-6.5.2 Inhalation of Dusts

Inhalation Exposure from Dust on Outdoor Summer Days

Contribution from outside airborne dust:

$$EXP_{SIAO}\ (\mu g/kg/day) = \frac{AI\ (m^3/d) \times SL\ (\mu g/g) \times AF_{inh} \times SODL\ (g/m^3) \times SOD(day/yr)}{BW\ (kg) \times DPY}$$

where:

EXP_{SIAO} = inhalation exposure to chemical from summer outside airborne dust (μg/kg/day)
AI = amount of air inhaled (13.19 m^3/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g)
AF_{inh} = fraction of chemical absorbed by receptor by inhalation (benzene, 0.79)
SODL = background dust level in outside air (0.000021 g/m^3; calculated above)
SOD = number of summer days spent outside per yr (68 days/yr)
BW = receptor body weight (16.4 kg)
DPY = number of days per year(365 days)

According to the above equation and input parameters, benzene exposure via inhalation of outside dust was estimated to be 0.00000756 μg/kg body weight/day (adjusted for bioavailability).

Contribution from Indoor Airborne Dust on Summer Days

$$EXP_{SIAI}\ (\mu g/kg/day) = \frac{AI\ (m^3/d) \times SL\ (\mu g/g) \times AF_{inh} \times SIDL\ (g/m^3) \times SID(d/yr)}{BW\ (kg) \times DPY}$$

where:

EXP_{SIAI} = summer inhalation exposure to chemical from summer indoor airborne dust (μg/kg/day)
AI = amount of air inhaled (13.19 m^3/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g),
AF_{inh} = fraction of chemical absorbed by receptor by inhalation (benzene, 0.79)
SIDL = background dust level in indoor air (0.0000157 g/m^3; calculated above)
SID = number of summer days spent indoors (206 days/yr)
BW = receptor body weight (16.4 kg)
DPY = number of days per year (365 days)

Benzene exposure from inhalation of outside dust was estimated to be 0.0000175 μg/kg body weight/day (adjusted for bioavailability).

Inhalation Exposure from Dust on Outdoor Winter Days

It was assumed that 10% of the summer outside dust level was available during the winter months denoted as PWS.

Contribution from outside airborne dust:

$$EXP_{WIAO}\ (\mu g/kg/day) = \frac{AI\ (m^3/d) \times SL\ (\mu g/g) \times AF_{inh} \times WODL\ (g/m^3) \times PWS \times WOD(day/yr)}{BW\ (kg) \times DPY}$$

where:
EXP_{WIAO} = winter inhalation exposure to benzene from outside airborne dust (μg/kg/day)
AI = amount of air inhaled (13.19 m^3/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g),
AF_{inh} = fraction of chemical absorbed by receptor by (benzene, 0.79)
WODL = background dust level in outside air (0.000021 g/m^3)
PWS = percentage of winter soil available (10%)
WOD = number of winter days spent outside per yr (22.8 days/yr)
BW = receptor body weight (16.4 kg)
DPY = number of days per year (365 days/year)

Exposure to benzene from inhalation of outside dust was estimated to be 0.00000025 μg/kg body weight/day (adjusted for bioavailability).

Contribution from Indoor Airborne Dust on Winter Days

$$EXP_{WIAI}\ (\mu g/kg/day) = \frac{AI\ (m^3/d) \times SL\ (\mu g/g) \times AF_{inh} \times WIDL\ (g/m^3) \times PWS \times WID(day/yr)}{BW\ (kg) \times DPY}$$

where:
EXP_{WIAI} = winter inhalation exposure to chemical from indoor airborne dust (μg/kg/day)
AI = amount of air inhaled (13.19 m^3/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g)
AF_{inh} = fraction of chemical absorbed by receptor by inhalation (benzene, 0.79)
WIDL = background dust level in indoor air (0.0000157 g/m^3; default value)
PWS = percentage of winter soil available(10%)
WID = number of winter days spent indoors (68 days/yr)
BW = receptor body weight (16.4 kg)
DPY = number of days per year (365 days/year)

According to the above equation and input parameters, benzene exposure due to inhalation of outside dust was estimated to be 0.000000564 μg/kg body weight/day (adjusted for bioavailability).

Total Exposure (Inhalation of Dusts)

$$EXP_{INH}=EXP_{SIAO}+EXP_{SIAI}+EXP_{WIAO}+EXP_{WIAI}$$

EXP_{INH} = total inhalation exposure (μg/kg/day)

EXP_{SIAO} = summer inhalation exposure to chemical from outside airborne dust (benzene, 0.00000756 μg/kg/day)

EXP_{SIAI} = summer inhalation exposure to chemical from indoor airborne dust (benzene, 0.0000171 μg/kg/day)

EXP_{WIAO} = winter inhalation exposure to chemical from outside airborne dust (benzene, 0.00000025 μg/kg/day)

EXP_{WIAI} = winter inhalation exposure to chemical from indoor airborne dust (benzene, 0.000000564 μg/kg/day)

The total benzene exposure due to impacted dust was estimated to be 0.0000255 μg/kg/day.

E-6.5.3 Ingestion of Soil/Dusts

The following provide the calculation of potential exposures via the ingestion of soil/dust:

Incidental Outdoor Soil Ingestion During Summer Months

Contribution from outside soil:

$$EXP_{SGAO}\ (\mu g/kg/day) = \frac{AO\ (g/d) \times SL\ (\mu g/g) \times FRSOIL \times AF_{oral} \times SOD}{BW\ (kg) \times DPY}$$

where:

EXP_{SGAO} = exposure from incidental ingestion of outside soil during summer

AO = amount of dust ingested (0.40 g/day; U.S. EPA, 1997)

SL = concentration of chemical in soil (3.04 μg/g)

AF_{oral} = percentage of chemical absorbed by receptor by ingestion of dust/soil (97%)

FRSOIL = percentage of soil/dust ingestion rate attributed to outdoor sources (45%;U.S. EPA, 1994)

SOD = total number of days spent on the site (indoors and outdoors; 274 days) during the summer

BW = receptor body weight (16.4 kg)

DPY = averaging time (365 days)

Exposure from incidental ingestion of outdoor soil during the summer was estimated to be 0.024 µg/kg/day.

Incidental Indoor Dust Ingestion During Summer Months

Contribution from indoor dust:

$$EXP_{SGAI}\ (\mu g/kg/day) = \frac{AO\ (g/d) \times SL\ (\mu g/g) \times 0.70 \times FRDUST \times AF_{oral} \times SOD}{BW\ (kg) \times DPY}$$

where:

EXP_{SGAI} = exposure from incidental ingestion of indoor dust during summer
AO = amount of soil/dust ingested (0.40 g/day; U.S. EPA, 1997)
SL = concentration of chemical in soil (3.04 µg/g)
AF_{oral} = percentage of chemical absorbed by receptor by ingestion of dust/soil (97%)
FRDUST = percentage of soil/dust ingestion rate attributed to indoor sources (55%;U.S. EPA, 1994)
SOD = total number of days spent on the site (indoors and outdoors; 274 days) during the summer
BW = receptor body weight (16.4 kg)
DPY = averaging time (365 days)
0.70 = fraction of dust originating from outdoor soil sources (U.S. EPA, 1994)

Benzene exposure from incidental ingestion of indoor dust during the summer was estimated to be 0.0208 µg/kg/day.

Incidental Outdoor Soil Ingestion During Winter Months

Contribution from outside soil:

$$EXP_{WGAO}\ (\mu g/kg/day) = \frac{AO\ (g/d) \times SL\ (\mu g/g) \times WDF \times FRSOIL \times AF_{oral} \times WOD}{BW\ (kg) \times DPY}$$

where:

EXP_{WGAO} = exposure from incidental ingestion soil in winter
AO = amount of dust ingested (0.40 g/day; U.S. EPA, 1998)
SL = concentration of chemical in soil (3.04 µg/g)
AF_{oral} = percentage of chemical absorbed by receptor by ingestion of dust/soil (97%)
FRSoil = percentage of the soil/dust ingestion rate attributed to outdoor sources (45%;U.S. EPA, 1994)
WOD = total number of days spent on the site (indoors and outdoors; 90.8 days) during the winter

WDF = winter soil/dust covering factor (0.10)
BW = receptor body weight (16.4 kg)
DPY = averaging time (365 days)

Exposure from incidental ingestion of outdoor soil during the winter was estimated to be 0.00080 μg/kg/day.

Incidental Indoor Dust Ingestion During Winter Months

Contribution from indoor dust:

$$EXP_{WGAI}\ (\mu g/kg/day) = \frac{AO\ (g/d) \times SL\ (\mu g/g) \times 0.70 \times WDF \times FRDUST \times AF_{oral} \times WOD}{BW\ (kg) \times DPY}$$

where:
EXP_{WGAI} = exposure from incidental ingestion of indoor dust during winter
AO = amount of soil/dust ingested (0.40 g/day; U.S. EPA, 1997)
SL = concentration of chemical in dust (3.04 μg/g)
AF_{oral} = percentage of chemical absorbed by receptor by ingestion of dust/soil (97%)
FRDUST = percentage of the soil/dust ingestion rate attributed to indoor sources (55%;U.S. EPA, 1994)
WOD = total number of days spent on the site (indoors and outdoors; 90.8 days) during the winter months
WDF = Winter dust covering factor (10%)
BW = receptor body weight (16.4 kg)
DPY = averaging time (365 days)
0.70 = fraction of dust originating from outdoor soil sources (U.S. EPA, 1994)

Benzene exposure from incidental ingestion of indoor dust during the winter was estimated to be 0.00068 μg/kg/day.

Total Exposure (Ingestion)

$$EXP_{ING} = EXP_{SGAO} + EXP_{WGAO} + EXP_{SGAI} + EXP_{WGAI}$$

EXP_{ING} = total oral exposure to benzene from incidental ingestion of indoor soil/dust
EXP_{SGAO} = oral exposure to benzene from incidental ingestion of summer outside dust/soil (0.024 μg/kg/day)
EXP_{WGAO} = oral exposure to benzene from incidental ingestion of outside dust/soil in winter (0.0208 μg/kg/day)
EXP_{SGAI} = oral exposure to benzene from incidental ingestion of inside dust during the summer (0.00080 μg/kg/day)

EXP_{WGAI} = oral exposure to benzene from incidental ingestion of inside dust during winter (0.00068 μg/kg/day)

According to the above equation, the total benzene exposure via incidental ingestion of indoor/outdoor soil/dust was estimated to be 0.046 μg/kg body weight/day.

E-6.5.4 Dermal Contact with Soil/Dust

Dermal Exposure from Soil/Dust on Outdoor Summer Days

Contribution from outside soil/dust:

$$EXP_{SDAO}\ (\mu g/kg/day) = \frac{EO\ (m^2) \times DSO\ (g/m^2/day) \times SL\ (\mu g/g) \times AF_{dermal} \times SOD}{BW(kg) \times DPY}$$

where:
EXP_{SDAO} = dermal exposure to chemical from contact with outside soil/dust in summer (μg/kg/day)
EO = area of exposed skin when outside (0.462 m^2)
DSO = soil/dust adherence factor (10 g/m/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g)
AF_{dermal} = fraction of chemical absorbed by receptor by dermal contact with soil/dust (benzene, 0.01)
SOD = number of summer days spent outdoors (68 days)
BW = receptor body weight (16.4 kg)
DPY = number of days per year (365 days)

Benzene exposure from dermal contact with summer outside soil/dust was estimated to be 0.0016 μg/kg/day (adjusted for bioavailability).

Contributions from indoor soil/dust:

$$EXP_{SDPI}\ (\mu g/kg/day) = \frac{EI\ (m^2) \times DSO\ (g/m^2/d) \times SL\ (\mu g/g) \times 0.7 \times AF_{dermal} \times SID}{BW\ (kg) \times DPY}$$

where:
EXP_{SDPI} = dermal exposure to chemical from contact with indoor soil/dust in summer (μg/kg/day)
EI = area of exposed skin when indoors (0.462 m^2)
DSO = soil/dust adherence factor (10 g/m^2/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g)
AF_{dermal} = fraction of chemical absorbed by receptor by dermal contact with soil/dust (benzene, 0.01)
SID = number of days spent indoors on site (206 days/year)

BW = receptor body weight (16.4 kg)
DPY = number of days per year (365 days)
0.70 = fraction of dust originating from outdoor soil sources (U.S. EPA, 1994)

According to the above equation and input parameters, benzene exposure via dermal contact with indoor soil/dust was estimated to be 0.00338 μg/kg/day (adjusted for bioavailability).

Dermal Exposure from Soil/Dust on Outdoor Winter Days

Contribution from outside soil/dust:

$$EXP_{WDAO}\ (\mu g/kg/day) = \frac{EO\ (m^2) \times PWS \times DSO\ (g/m^2/day) \times SL\ (\mu g/g) \times AF_{dermal} \times WOD}{BW(kg) \times DPY}$$

where:
EXP_{WDAO} = dermal exposure to chemical from contact with outside soil/dust in winter (μg/kg/day)
EO = area of exposed skin when outside (0.163 m^2)
PWS = percentage of winter soil available(10%)
DSO = soil/dust adherence factor (10 g/m^2/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g)
AF_{dermal} = fraction of chemical absorbed by receptor by dermal contact with soil/dust (benzene, 0.01)
WOD = number of winter days spent outdoors (22.8 days)
BW = receptor body weight (16.4 kg)
DPY = number of days per year (365 days)

Thus, according to the above equation and input parameters, the exposure to benzene from dermal contact with winter outside soil/dust was estimated to be 0.000019 μg/kg/day (adjusted for bioavailability).

Contributions from indoor soil/dust:

$$EXP_{WDPI}\ (\mu g/kg/day) = \frac{EI\ (m^2) \times DSO\ (g/m^2/d) \times SL\ (\mu g/g) \times PWS \times 0.7 \times AF_{dermal} \times WID}{BW\ (kg) \times DPY}$$

where:
EXP_{WDPI} = dermal exposure to chemical from contact with indoor soil/dust in winter (μg/kg/day)
EI = area of exposed skin when indoors (0.163 m^2)
DSO = soil/dust adherence factor (10 g/m^2/day)
SL = concentration of chemical in soil (benzene, 3.04 μg/g)
PWS = percentage of winter soil available(10%)
AF_{dermal} = fraction of chemical absorbed by receptor by dermal contact with soil/dust

(benzene, 0.01)
WID = number of days spent indoors on site (68 days/year)
BW = receptor body weight (16.4 kg)
DPY = number of days per year(365 days)
0.70 = fraction of dust originating from outdoor soil sources (U.S. EPA, 1994)

Benzene exposure from dermal contact with indoor dust was estimated to be 3.94e-5 µg/kg/day (adjusted for bioavailability).

Total Exposure (Dermal)

$$EXP_{DERM} = EXP_{SDAO} + EXP_{SDPI} + EXP_{WDAO} + EXP_{WDPI}$$

EXP_{DERM} = total dermal exposure to chemical from contact with outside/dust (µg/kg/day)
EXP_{SDAO} = dermal exposure to chemical from contact with summer outside soil/dust (benzene, 0.0016 µg/kg/day)
EXP_{SDPI} = dermal exposure to chemical from contact with summer indoor soil/dust (benzene, 0.00338 µg/kg/day)
EXP_{WDAO} = dermal exposure to chemical from contact with winter outside soil/dust (benzene, 0.000019 µg/kg/day)
EXP_{WDPI} = dermal exposure to chemical from contact with winter indoor soil/dust (benzene, 0.0000394 µg/kg/day)

According to the above equation and input parameters, the total benzene exposure from dermal contact with indoor soil/dust was estimated to be 0.00504 µg/kg/day .

E-6.5.5 Inhalation and Dermal Exposure from Soil Vapours

Inhalation Exposure from Soil Vapours

Contribution from outside summer/winter air:

$$EXP_{VASO}\ (\text{ug/kg/day}) = \frac{C_{AIR}\ (\text{ug/m}^3) \times AI\ (\text{m}^3\text{/d}) \times SID\ (\text{day/yr}) \times AF_{inh}}{BW\ (\text{kg}) \times DPY(\text{day/yr})}$$

where:
EXP_{VASO} = inhalation exposure to chemical from outside vapours from soil-borne material (µg/kg/day)
C_{AIR} = concentration of chemical in outside air resulting from soil (0.017 µg/m³)
AI = amount of air inhaled (13.19 m³/day)
AF_{inh} = fraction of chemical absorbed by receptor by inhalation (0.79)
DPY = number of days per year (365 days)
SID = number of summer/winter days spent outdoor on site (68 summer

days/year; 22.8 winter days/year)
BW = receptor body weight (16.4 kg)

According to the above equation and input parameters the benzene inhalation exposure due to inhalation of outside vapours from soil was estimated to be 0.0027 μg/kg/day for summer and winter.

Dermal Exposure from Soil Vapours

$$EXP_{VASD}\ (ug/kg/day) = \frac{C_{AIR}\ (ug/m^3) \times cdpcvap\ (m/h) \times SA\ (m^2) \times SID \times cvpf \times Hpd\ (h)}{BW\ (kg) \times DPY}$$

Contribution from outside air during summer and winter months:

where:
EXP_{VASD} = benzene exposure via dermal contact with vapours originating from impacted soils ($\mu g/kg/day$)
C_{AIR} = concentration of benzene in outside air resulting from soil (0.017 $\mu g/m^3$)
cdpcvap = vapor permeability constant (0.00206 m/h)
SA = whole body surface area (0.5798 m^2)
Hpd = hours per day (24 h/day)
BW = receptor body weight (16.4 kg)
cvpf = vapour particulate phase fraction (0.99)
SID = number of summer and winter days spent outside (68 + 22.8 days/year)
DPY = days per year (365 days/year)

According to the above equation and input parameters benzene exposure via dermal contact with outside vapors originating from soil was estimated to be 0.00000740 μg/kg/day.

Estimating Outside Air Concentrations (C_{air})

C_{air}, the outside air concentration resulting from soil vaporization, is calculated as follows:

The first step is to calculate a soil adsorption coefficient (K_d) using the following equation provided by Karickhoff (1981).

$$K_d = K_{oc} \text{ x } f_{oc} \text{ x } 1.0e^{-6}(m^3/ml), \quad \text{where: } K_{oc} = 0.411 * K_{ow}$$

where:
K_d = soil adsorption coefficient (m^3/g)
K_{ow} = octanol water partitioning coefficient (134.9 (g/g)/(g/ml))
K_{oc} = octanol carbon partitioning coefficient (55.44)
f_{oc} = fraction of organic carbon in the soil (0.01 g/g)

From the above equation and input parameters, the soil adsorption coefficient for benzene was estimated to be 0.000000554 m³/g.

Now that the soil adsorption coefficient has been calculated, the soil air multiplier (C_{sa}) can be derived. This equation is based on formula provided by Lyman *et al.* (1982).

$$C_{sa} = H_u / K_d$$

where:

C_{sa} = soil-air multiplier (g/m³)
H_u = unitless Henry's Law Constant = H/(RT)
H = Henry's Law Constant (benzene, 557 Pa m³/mol)
T = temperature (283 K)
R = universal gas constant (8.314 m³Pa/mol K)
K_d = soil adsorption coefficient (0.000000554 m³/g)

The soil-air multiplier was estimated to be 427315.82 g/m³.

The rate of chemical volatilization from the soil into the outside air is influenced by soil properties, chemical properties and environmental conditions. Several methods have been reported which can be used to predict chemical concentrations in air derived from the volatilization of chemicals in soil. Most of these methods do not address all the factors that influence vaporization and thus the models are not extremely accurate, however, they are useful as being generally indicative of environmental behaviour. In order to estimate a volatile contaminate flux rate, the following equation(s) were used:

$$N = K_o (C_{sa} - C_{si})$$

where:

N = substance flux rate (g/m²h)
K_o = overall mass transfer coefficient (0.00043 m/h)
C_{sa} = concentration in soil-air (427315.82 μg/m²)
C_{si} = concentration in air at the soil-surface interface (0 g/m³; assumed in order to maximize flux of the chemical from the soil-air into the air)

From the above equation and input parameters the flux rate of benzene was estimated to be 183 g/m²h.

The over mass transfer coefficient (K_o) can be determined from:

$$\frac{1}{K_o} = \frac{1}{K_g} + \frac{1}{K_s}$$

where:

K_o = overall mass transfer coefficient (m/h)
K_g = gas phase transfer coefficient at the soil surface (28.5 m/h; Golder, Senes and CanTox, 1986)
K_s = diffusive mass transfer coefficient for soil (0.00043 m/h; Golder, Senes and CanTox, 1986).

From the above equation and input parameters the overall mass transfer coefficient was estimated to be 0.00043 m/h.

The air concentration multiplier was calculated as:

$$C_a = \frac{N\ A_f\ R_t}{V_b}$$

where:
C_a = air concentration multiplier (g/m^3)
A_f = flux area of 1 m by 1 m = 1 m^2
R_t = average residence time (0.0000617 h; calculated below)
V_b = volume of the box (2 m^3; assumed)
N = substance flux rate 183 (g/m^2h; calculated above)

The air concentration multiplier was estimated to be 0.0056 g/m^3.

To estimate the exposure that a receptor would receive, a "box" (that surrounds the receptor) with dimensions 1 m wide by 1 m deep by 2 m high was used to simulate the volume of air that the receptor draws from. Assuming an average wind speed of 16.2 km/h, such a box has an average residence time (R_t) of 6.17×10^{-5} h, calculated as follows:

$$R_t\ (h) = \frac{\sqrt{A_f\ (m2)}}{WS\ (km/h) \times 1000\ (m/km)}$$

where:
R_t = average residence time (h) = 6.17×10^{-5} h
A_f = flux area of 1 m by 1 m = 1 m^2
WS = wind speed (16.2 km/h; assumed)

$$C_{AIR} = C_a \times C_s$$

where:
C_{AIR} = concentration in air ($\mu g/m^3$)
C_a = concentration air multiplier (0.0056 g/m^3)
C_s = soil concentration (3.04 $\mu g/g$)

Thus from the above equation and input parameters, the concentration of benzene in outside air resulting from soil was estimated to be 0.017 $\mu g/m^3$.

E-7.0 RISK CHARACTERIZATION

Total exposure was calculated by summing the individual exposures from each media (air, soil, water and vegetation) for all relevant exposure pathways, on a site by site, chemical by chemical and receptor by receptor basis. Exposure Ratios were estimated using the equations provided below and the exposure values previously calculated.

$$ER = \frac{EI_{INHALATION(Bioavailability\ Adjusted)}}{EL_{INHALATION(Bioavailability\ Adjusted)}} + \frac{EI_{ORAL+DERMAL(Bioavailability\ Adjusted)}}{EL_{ORAL(Bioavailability\ Adjusted)}}$$

where:

ER = exposure ratio

EI = total daily exposure to the female toddler to benzene from the air, soil, water and vegetation pathways (μg/kg body weight/day)

The total inhalation benzene exposure was estimated to be approximately 1.53 (μg/kg bw/day). Applying a carcinogenic amortized factor of 0.064 (*i.e.,* 4.5 years/70 years) produces an adjusted exposure estimate of 0.0984 μg/kg bw/day (*i.e.*, 4.5/70 x 1.53 = 0.0984).

The total exposure *via* oral and dermal routes were estimated to be approximately 5.36 (μg/kg bw/day); after applying an amortization factor of 0.064, an adjusted exposure estimate of 0.343 (μg/kg bw/day) was generated.

EL_{INH} = an inhalation slope factor (q1*) for benzene was reported to be 0.000025 (μg/kg body weight/day)$^{-1}$. This slope factor was converted to an RsD, (*i.e.*, 0.00001/0.000025) and then adjusted by the inhalation bioavailability of 0.79 to produced a risk-specific dose (RsD) of 0.316 (μg/kg body weight/day)

EL_{ORAL} = an oral slope factor (q1*) for benzene was reported to be 0.000029 (μg/kg body weight/day)$^{-1}$. This slope factor was converted to an RsD of 0.45 (*i.e.*, 0.00001/0.000029) and then adjusted by the oral bioavailability of 0.97 to produce a RsD of 0.334 (μg/kg body weight/day).

A benzene exposure ratio for a female toddler was estimated to be 1.34.

E-8.0 MODIFICATIONS OF EXPOSURE ESTIMATES BASED ON BIOAVAILABILITY

Not all chemicals are 100% bioavailable. This means that not all of the chemical in the exposure medium (*e.g.*, air, soil, food, water) would be absorbed into the body. Thus, only a fraction of the chemical in the exposure medium will contribute to the body burden of the chemical and therefore to the development of toxic effects. It is only important to consider the degree of bioavailability of the chemical when the exposure medium or route is markedly different between the conditions under which the exposure limit was developed compared with the exposure conditions under assessment. If there was a substantial difference in the two exposure conditions for a particular chemical, the exposure estimate was modified appropriately. For example, if the exposure limit for a particular chemical was established from animal studies where the chemical was injected into the trachea in a solution, but the chemical was adsorbed to airborne particles, dusts and soils, the exposure estimate would be reduced proportional to the difference in the bioavailability of the chemical between the two conditions.

In all cases where exposure modifications were made based on bioavailability, the highest estimates of bioavailability for airborne chemicals bound to particulates were used as the upper bound of the range. If no information was available on the bioavailability of a chemical, it was assumed that the chemical was 100% bioavailable. Both these scenarios would tend to over-estimate exposure levels and therefore over-estimate the potential health risks associated with chemicals bound to particulates. However, if a chemical were less than 100% bioavailable but no information was available, the assumption of 100% bioavailability in estimating the exposure limit would under estimate the potential toxic potency of the chemical.

E-9.0 CANCER RISKS FOR RECEPTORS EXPOSED TO CHEMICALS FROM THE SITE FOR THEIR ENTIRE LIFETIME (*I.E.*, COMPOSITE RECEPTORS)

It should be noted that for chemicals that act as direct, genotoxic carcinogens (*i.e.*, directly induce self-propagated lesions), the dose of the chemicals associated with a specified level of risk (one in a hundred thousand for this assessment) of death due to cancer (*i.e.*, expressed as the RsD) increases with the duration of exposure. The methodology used in estimating the RsD for such chemicals assumes that the exposure occurs over the lifetime of a human receptor (*i.e.*, 70 years for typical humans), hence each life stage exposure estimate was adjusted by the appropriate amortization factor.

The level of risk for the composite receptor was calculated by adding the adjusted ER values calculated for each individual life stage (adjusted for duration of exposure) in order to estimate the lifetime cancer risk. The compilation of all 5 individual life stages (infant, 0.5/70; toddler, 4.5/70; child, 7/70; youth, 8/70; adult, 50/70) results in a risk estimate for the composite or lifetime (70/70) receptor. Given the acceptable cancer risk level (*i.e.*, 1 in 100,000 for this assessment), the composite ER can then be expressed as an incremental lifetime cancer risk (ILCR).

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APPENDIX F

PHYSICAL/CHEMICAL PROPERTIES OF SELECTED CHEMICALS

F-1.0 PHYSICAL AND CHEMICAL PROPERTIES AND BACKGROUND CONCENTRATIONS OF CHEMICALS EVALUATED QUANTITATIVELY IN THE PHRA

Physical and chemical properties and background concentrations of chemicals quantitatively evaluated in the IOL Refinery Upgrade PHRA are provided in the following sections.

F-1.1 Physical/Chemical Properties of Anthracene and Background Concentrations of Anthracene and Related Chemicals

A summary of the physical and chemical properties of anthracene and background concentrations of anthracene and related chemicals are summarized in Table F-1.

Table F-1 Physical and chemical properties of anthracene and typical background concentrations of anthracene and related chemicals

Parameter	Value	Reference
Molecular Weight	178.2 g/mol	Mackay *et al.*, 1992
log K_{ow}	4.54	Mackay *et al.*, 1992
log K_{OC}	4.41	API, 1984
Henry's Law Constant	$3.96 \text{ Pa} \cdot \text{m}^3/\text{mol}$	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.024/0.924	Mackay *et al.*, 1992
Vapour Pressure	0.001 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m²/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m²/s	U.S. EPA, 1992
Solubility	45 mg/m³	Mackay *et al.*, 1992
Soil half-life	1200-11010 hours	Howard *et al.*, 1991
Air half-life	0.58-1.7 hours	Howard *et al.*, 1991
Surface water half-life	0.58-1.7 hours	Howard *et al.*, 1991
Ground water half-life	2400-22080 hours	Howard *et al.*, 1991
Water-to-fish BCF	9120	Mackay *et al.*, 1992
Beef transfer coefficient	0.00087 day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	0.00028 day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	0.044	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	0.092	Calculated from Travis and Blaylock, 1992

Table F-1 **Physical and chemical properties of anthracene and typical background concentrations of anthracene and related chemicals**

Parameter	Value	Reference
Background air concentration		
anthracene	0.00047, 0.00173 μg/m^3 (St. Andrews; mean, 95th percentile)	NB DOE, 1999
9,10-dimethylanthracene	NDA	
Background water concentration		
anthracene	0.0002 μg/L (Niagara River)	GC/EC/HC, 1994
9,10-dimethylanthracene	0-0.00019 μg/L (Ottawa)	Benoit *et al.*, 1979
Background soil concentration		
anthracene	0.16 μg/g (land uses other than agricultural)	MOE, 1997
9,10-dimethylanthracene	NDA	

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F-2.1 Physical/Chemical Properties of Benzo[a]pyrene and Background Concentrations of Benzo[a]pyrene and Related Chemicals

A summary of the physical and chemical properties of benzo[a]pyrene and background concentrations of benzo[a]pyrene and related chemicals are summarized in Table F-2.

Table F-2 Physical and chemical properties of benzo[a]pyrene and typical background concentrations of benzo[a]pyrene and related chemicals

Parameter	Value	Reference
Molecular Weight	252.3 g/mol	Mackay *et al.*, 1992
log K_{ow}	6.04	Mackay *et al.*, 1992
log K_{OC}	6.65	Reinhold *et al.*, 1978
Henry's Law Constant	0.046 Pa · m^3/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0/0.977	Mackay *et al.*, 1992
Vapour Pressure	7×10^{-7} Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	3.8 mg/m^3	Mackay *et al.*, 1992
Soil half-life	1368-12720 hours	Howard *et al.*, 1991
Air half-life	0.37-1.1 hours	Howard *et al.*, 1991
Surface water half-life	0.37-1.1 hours	Howard *et al.*, 1991
Ground water half-life	2736-25440 hours	Howard *et al.*, 1991
Water-to-fish BCF	282	Mackay *et al.*, 1992
Beef transfer coefficient	0.028 day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	0.0087 day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	119	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	0.013	Calculated from Travis and Blaylock, 1992

Table F-2 Physical and chemical properties of benzo[a]pyrene and typical background concentrations of benzo[a]pyrene and related chemicals

Parameter	Value	Reference
Background air concentration		
benzo[a]pyrene	0.000019, 0.0000610 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	NB DOE, 1999
benzo[a]anthracene	0.000012, 0.0000940 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
benzo[b]fluoranthene	0.0000776,0.000203 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
benzo[b]chrysene	0.000011, 0.0000190 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
benzo[k]fluoranthene	0.0000142, 0.0000310 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
benzo[g,h,i]perylene	0.0000388, 0.000124 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
benzo[b]fluorene	0.0000112, 0.00002 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
anthanthrene	0.0000115, 0.0000198 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
benzo[e]pyrene	0.000215 $\mu g/m^3$ (St. Andrews; mean)	
chrysene	0.0000371, 0.000123 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
dibenzo[a,h]&[a,c]anthracene	0.0000113, 0.0000198 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
7-methylbenzo[a]anthracene	0.0000110, 0.0000190 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
indeno[1,2,3-c,d]pyrene	0.0000354, 0.000114 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
2-methylcholanthrene	0.0000110, 0.0000190 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
perylene	0.0000110, 0.0000190 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
phenanthrene	0.00104, 0.00196 $\mu g/m^3$ (St. Andrews; mean, 95th percentile)	
Background water concentration		
benzo[a]pyrene	0.003 $\mu g/L$ (Atlantic surface water)	CCME, 1992
benzo[a]anthracene	0 (Toronto area)	MOE, 1988a,b
benzo[b&k]fluoranthene	0 (Toronto area)	MOE, 1988a,b
benzo[a]fluorene	0-0.00005 $\mu g/L$ (Ottawa)	Benoit *et al.*, 1979
benzo[b]fluorene	0-0.00005 $\mu g/L$ (Ottawa)	Benoit *et al.*, 1979
benzo[g,h,i]perylene	0	MOE, 1988a
benzo[e]pyrene	0	MOE, 1988a
chrysene	0	MOE, 1988a
dibenzo[a,h]anthracene	0	MOE, 1988a
7,12-dimethylbenzo[a]anthracene	NDA	
indeno[1,2,3-c,d]pyrene	NDA	
3-methylcholanthrene	NDA	
perylene	0	MOE, 1988a
phenanthrene	0.0176 (Quebec)	GC/EC/HC, 1994

Table F-2 Physical and chemical properties of benzo[a]pyrene and typical background concentrations of benzo[a]pyrene and related chemicals

Parameter	Value	Reference
Background soil concentration		
benzo[a]pyrene	0.49 μg/g (land uses other than agricultural)	MOE, 1997
benzo[a]anthracene	0-6 μg/g (Halifax)	JWEL, 1991
benzo[b&k]fluoranthene	0-2.5 μg/g (Halifax)	JWEL, 1991
benzo[a]fluorene	NDA	
benzo[b]fluorene	NDA	
benzo[g,h,i]perylene	0-4 μg/g (Halifax)	JWEL, 1991
benzo[e]pyrene	0.363 μg/g	Butler *et al.*, 1984
chrysene	0-2 μg/g (Halifax)	JWEL, 1991
dibenzo[a,h]anthracene	0-4 μg/g (Halifax)	JWEL, 1991
7,12-dimethylbenzo[a]anthracene	NDA	
indeno[1,2,3-c,d]pyrene	0-4 μg/g (Halifax)	JWEL, 1991
3-methylcholanthrene	NDA	
perylene	NDA	
phenanthrene	0.69 μg/g (land uses other than agricultural)	MOE, 1997

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F-3.1 Physical/Chemical Properties and Background Concentrations of Benzene

A summary of the physical and chemical properties of benzene and its background concentrations are summarized in Table F-3.

Table F-3 Physical and chemical properties and typical background concentrations of benzene

Parameter	Value	Reference
Molecular Weight	78.11 g/mol	Mackay *et al.*, 1992
log K_{ow}	2.13	Mackay *et al.*, 1992
log K_{OC}	1.92	Mackay *et al.*, 1992
Henry's Law Constant	557 Pa · m³/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.9901/0.0010	Mackay *et al.*, 1992
Vapour Pressure	12,700 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m²/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m²/s	U.S. EPA, 1992
Solubility	1,780,000 mg/m³	Mackay *et al.*, 1992
Soil half-life	120-384 hours	Howard *et al.*, 1991
Air half-life	50.1-501 hours	Howard *et al.*, 1991
Surface water half-life	120-384 hours	Howard *et al.*, 1991
Ground water half-life	240-17,280 hours	Howard *et al.*, 1991
Water-to-fish BCF	12.6	Mackay *et al.*, 1992
Beef transfer coefficient	3.4×10^{-6} day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	1.1×10^{-6} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	1.2×10^{-6}	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	2.27	Calculated from Travis and Blaylock, 1992
Background air concentration	0.469, 0.766 μg/m³ (Pt. Lepreau; mean, 95th percentile value)	NB DOE, 1999
Background water concentration	< 1 μg/L (Canadian surface waters)	GC/EC/HC, 1993
Background soil concentration	0.002 μg/g soil (all land uses)	MOE, 1997

F-3.2 References

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F-4.1 Physical/Chemical Properties of 1,3-Butadiene and Background of 1,3-Butadiene and Related Chemicals

A summary of the physical and chemical properties of 1,3-butadiene and background concentrations of 1,3-butadiene and related chemicals are summarized in Table F-4.

Table F-4 Physical and chemical properties of 1,3-butadiene and typical background concentrations of 1,3-butadiene and related chemicals

Parameter	Value	Reference
Molecular Weight	54.09 g/mol	Mackay *et al.*, 1993
log K_{ow}	1.99	Mackay *et al.*, 1993
log K_{OC}	2.36	Mackay *et al.*, 1993
Henry's Law Constant	20, 679 Pa · m^3/mol	Mackay *et al.*, 1993
Vapour/Particulate Phase Fraction	0.9997/0.00002	Mackay *et al.*, 1993
Vapour Pressure	281,000 Pa	Mackay *et al.*, 1993
Deposition velocity	0.015 m/s	Mackay, 1991
Solubility	735 mg/m^3	Mackay *et al.*, 1993
Soil half-life	168-672 hours	Howard *et al.*, 1991
Air half-life	0.76-7.8 hours	Howard *et al.*, 1991
Surface water half-life	168-672 hours	Howard *et al.*, 1991
Ground water half-life	336-1344 hours	Howard *et al.*, 1991
Water-to-fish BCF	19	Mackay *et al.*, 1993
Beef transfer coefficient	0.0000025 day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	0.00000078 day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	0.000000024	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	2.7	Calculated from Travis and Blaylock, 1992
Background air concentration		NB DOE, 1999
1,3-butadiene	0.01 - 0.02 ($\mu g/m^3$)	
Isoprene	0.01 - 1.12 ($\mu g/m^3$)	
Background water concentration	NDA	
Background soil concentration	NDA	

F-4.2 References

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F-5.1 Physical/Chemical Properties and Background Concentrations of Crotonaldehyde

The physical and chemical properties of crotonaldehyde and its background concentrations are summarized in Table F-5.

Table F-5 Physical and chemical properties and typical background concentrations of crotonaldehyde

Parameter	Value	Reference
Molecular Weight	70.09 g/mol	IPCS/CEC, 1993
log K_{ow}	0.63	IPCS/CEC, 1993
log K_{OC}	NDA	
Henry's Law Constant	NDA	
Vapour/Particulate Phase Fraction	NDA	
Vapour Pressure	4,000 Pa	IPCS/CEC, 1993
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	15-18 g/100 ml	IPCS/CEC, 1993
Soil half-life	24-168 hours	Howard *et al.*, 1991
Air half-life	1.94-17.9 hours	Howard *et al.*, 1991
Surface water half-life	24-168 hours	Howard *et al.*, 1991
Ground water half-life	48-336 hours	Howard *et al.*, 1991
Water-to-fish BCF	NDA	
Beef transfer coefficient	1.1×10^{-7} day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	3.4×10^{-8} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	NDA	
Soil-to-plant (dw) BCF	17	Calculated from Travis and Blaylock, 1992
Background air concentration	NDA	
Background water concentration	NDA	
Background soil concentration	NDA	

Notes: NDA=no data available

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F-6.1 Physical/Chemical Properties and Background Concentrations of Ethylbenzene

The physical and chemical properties of ethylbenzene and its background concentrations are summarized in Table F-6.

Table F-6 Physical and chemical properties and typical background concentrations of ethylbenzene

Parameter	Value	Reference
Molecular Weight	106.2 g/mol	Mackay *et al.*, 1992
log K_{ow}	3.13	Mackay *et al.*, 1992
log K_{OC}	2.38	Hodson and Williams, 1988
Henry's Law Constant	887 Pa · m^3/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.9880/0.0066	Mackay *et al.*, 1992
Vapour Pressure	1,270 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	152,000 mg/m^3	Mackay *et al.*, 1992
Soil half-life	72-240 hours	Howard *et al.*, 1991
Air half-life	8.56-85.6 hours	Howard *et al.*, 1991
Surface water half-life	72-240 hours	Howard *et al.*, 1991
Ground water half-life	144-5472 hours	Howard *et al.*, 1991
Water-to-fish BCF	145	Mackay *et al.*, 1992
Beef transfer coefficient	3.4×10^{-5} day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	1.1×10^{-5} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	7.6×10^{-6}	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	0.6	Calculated from Travis and Blaylock, 1992
Background air concentration	0.077, 0.153 μg/m^3 (Pt. Lepreau; mean, 95th percentile)	NB DOE, 1999
Background water concentration	<0.2 μg/L (U.S. groundwater)	U.S.G.S., 1998
Background soil concentration	0.002 μg/g (all land uses)	MOE, 1997

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F-7.1 Physical/Chemical Properties of Fluorene and Background Concentrations of Fluorene and Related Chemicals

A summary of the physical and chemical properties of fluorene and background concentrations of fluorene and related chemicals are summarized in Table F-7.

Table F-7 Physical and chemical properties of fluorene and typical background concentrations of fluorene and related chemicals

Parameter	Value	Reference
Molecular Weight	166.2 g/mol	Mackay *et al.*, 1992
log K_{ow}	4.18	Mackay *et al.*, 1992
log K_{OC}	4.15	Mackay *et al.*, 1992
Henry's Law Constant	7.87 Pa · m^3/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.0186/0.9815	Mackay *et al.*, 1992
Vapour Pressure	0.09 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	1,900 mg/m^3	Mackay *et al.*, 1992
Soil half-life	768-1440 hours	Howard *et al.*, 1991
Air half-life	6.81-68.1 hours	Howard *et al.*, 1991
Surface water half-life	768-1440 hours	Howard *et al.*, 1991
Ground water half-life	1536-2880 hours	Howard *et al.*, 1991
Water-to-fish BCF	1290	Mackay *et al.*, 1992
Beef transfer coefficient	0.00038 day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	0.00012 day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	0.0096	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	0.15	Calculated from Travis and Blaylock, 1992

Table F-7 Physical and chemical properties of fluorene and typical background concentrations of fluorene and related chemicals

Parameter	Value	Reference
Background air concentration		
fluorene	0.00051, 0.00126 μg/m^3 (St. Andrews; mean, 95th percentile)	NB DOE, 1999
phenanthrene	0.00104, 0.00196 μg/m^3 (St. Andrews; mean, 95th percentile)	
pyrene	0.000145, 0.000420 μg/m^3 (St. Andrews; mean, 95th percentile)	
fluoranthene	0.000254, 0.000564 μg/m^3 (St. Andrews; mean, 95th percentile)	
benzo[a]fluorene	0.0000160, 0.0000416 μg/m^3 (St. Andrews; mean, 95th percentile)	
benzo[g,h,i]fluoranthene	0.0000254, 0.0000896 μg/m^3 (St. Andrews; mean, 95th percentile)	
pyrene	0.000145, 0.000420 μg/m^3 (St. Andrews; mean, 95th percentile)	
triphenylene	0.0000254, 0.0000773 μg/m^3 (St. Andrews; mean, 95th percentile)	
Background water concentration		
fluorene	0.007 μg/L (Nova Scotia)	GC/EC/HC, 1994
phenanthrene	0.0176 μg/L (Quebec)	GC/EC/HC, 1994
pyrene	0.005 μg/L (Nova Scotia)	GC/EC/HC, 1994
fluoranthene	0.0008 μg/L (Niagara River)	GC/EC/HC, 1994
Background soil concentration		
fluorene	0.12 μg/g (land uses other than agricultural)	MOE, 1997
phenanthrene	0.69 μg/g (land uses other than agricultural)	MOE, 1997
pyrene	0.69 μg/g (land uses other than agricultural)	MOE, 1997
fluoranthene	0.69 μg/g (land uses other than agricultural)	MOE, 1997

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F-8.1 Physical/Chemical Properties and Background Concentrations of Methyl *tert*-Butyl Ether (MTBE)

A summary of the physical and chemical properties of methyl *tert*-butyl ether and its background concentrations are summarized in Table F-8.

Table F-8 Physical and chemical properties and typical background concentrations of methyl *tert*-butyl ether

Parameter	Value	Reference
Molecular Weight	88.15 g/mol	Mackay *et al.*, 1993
log K_{ow}	0.94	Mackay *et al.*, 1993
log K_{OC}	NDA	
Henry's Law Constant	70.31 $Pa \cdot m^3/mol$	Mackay *et al.*, 1993
Vapour/Particulate Phase Fraction	0.0005/0.9336	Mackay *et al.*, 1993
Vapour Pressure	33,500 Pa	Mackay *et al.*, 1993
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	42,000,000 mg/m^3	Mackay *et al.*, 1993
Soil half-life	672-4320 hours	Howard *et al.*, 1991
Air half-life	20.7-265 hours	Howard *et al.*, 1991
Surface water half-life	672-4320 hours	Howard *et al.*, 1991
Ground water half-life	1344-8640 hours	Howard *et al.*, 1991
Water-to-fish BCF	1.1	Fujiwara *et al.*, 1984
Beef transfer coefficient	2.2×10^{-7} day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	6.9×10^{-8} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	6.2×10^{-7}	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	11	Calculated from Travis and Blaylock, 1992
Background air concentration	0.09-0.72-3.07[a] $\mu g/m^3$ (Milwaukee)	CalEPA, 1997
Background water concentration	0.00012 $\mu g/L$ (modelled for Canada)	GC/EC/HC, 1992
Background soil concentration	2.8×10^{-7} $\mu g/g$ (modelled for Canada)	GC/EC/HC, 1992

Notes: NDA=no data available

a min-mean-max

F-8.2 References

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F-9.1 Physical/Chemical Properties of Naphthalene and Background Concentrations of Naphthalene and Related Chemicals

A summary of the physical and chemical properties of naphthalene and background concentration of naphthalene and related chemicals are summarized in Table F-9.

Table F-9 Physical and chemical properties of naphthalene and typical background concentrations of naphthalene and related chemicals

Parameter	Value	Reference
Molecular Weight	128.19 g/mol	Mackay *et al.*, 1992
log K_{ow}	3.37	Mackay *et al.*, 1992
log K_{OC}	2.97	ATSDR, 1995
Henry's Law Constant	43.01 Pa · m^3/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.7353/0.2648	Mackay *et al.*, 1992
Vapour Pressure	10.4 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	31,000 mg/m^3	Mackay *et al.*, 1992
Soil half-life	16.6-48 days	Howard *et al.*, 1991
Air half-life	2.96-29.6 hours	Howard *et al.*, 1991
Surface water half-life	12 hours-258 days	Howard *et al.*, 1991
Ground water half-life	24 hours-258 days	Howard *et al.*, 1991
Water-to-fish BCF	427	Mackay *et al.*, 1992
Beef transfer coefficient	5.9×10^{-5} day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	1.9×10^{-5} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	0.00027	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	0.44	Calculated from Travis and Blaylock, 1992
Background air concentration		NB DOE, 1999
acenaphthene	0.000135, 0.000381 $\mu g/m^3$ (St. Andrews; mean; 95th percentile)	
acenaphthylene	0.0000698, 0.0002021 $\mu g/m^3$ (St. Andrews; mean; 95th percentile)	
Background water concentration		
naphthalene	0.0036 $\mu g/L$ (Niagara River)	GC/EC/HC, 1994
acenaphthalene	0.01 $\mu g/L$ (Quebec)	GC/EC/HC, 1994
Background soil concentration		
naphthalene	0.09 $\mu g/g$ (land uses other than agricultural)	MOE, 1997
acenaphthalene	0.08 $\mu g/g$ (all land uses)	MOE, 1997

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F-10.1 Physical/Chemical Properties and Background Concentrations of Toluene

The physical and chemical properties of toluene and its background concentrations are summarized in Table F-10.

Table F-10 Physical and chemical properties and typical background concentrations of toluene

Parameter	Value	Reference
Molecular Weight	92.13 g/mol	Mackay *et al.*, 1992
log K_{ow}	2.69	Mackay *et al.*, 1992
log K_{oc}	2.28	Mackay *et al.*, 1992
Henry's Law Constant	680 Pa · m^3/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.9896/0.0031	Mackay *et al.*, 1992
Vapour Pressure	3,800 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility	515,000 mg/m^3	Mackay *et al.*, 1992
Soil half-life	96-528 hours	Howard *et al.*, 1991
Air half-life	10-104 hours	Howard *et al.*, 1991
Surface water half-life	96-528 hours	Howard *et al.*, 1991
Ground water half-life	168-672 hours	Howard *et al.*, 1991
Water-to-fish BCF	89	Mackay *et al.*, 1992
Beef transfer coefficient	1.2×10^{-5} day/kg	Calculated from Travis and Arms, 1988
Milk transfer coefficient	3.9×10^{-6} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF	3.6×10^{-6}	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF	1.1	Calculated from Travis and Blaylock, 1992
Background air concentration	0.598, 1.33 μg/m^3 (Pt. Lepreau; mean, 95th percentile)	NB DOE, 1999
Background water concentration	2 μg/L (Canadian drinking water)	GC/EC/HC, 1992
Background soil concentration	0.002 μg/g soil (all land uses)	MOE, 1997

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F-11.1 Physical/Chemical Properties and Background Concentrations of Xylenes

The physical and chemical properties of xylenes and their background concentrations are summarized in Table F-11.

Table F-11 Physical and chemical properties and typical background concentrations of xylenes

Parameter	Value	Reference
Molecular Weight	106.2 g/mol	Mackay *et al.*, 1992
log K_{ow}		
o-xylene	3.15	Mackay *et al.*, 1992
m-xylene	3.20	Mackay *et al.*, 1992
p-xylene	3.18	Mackay *et al.*, 1992
log K_{OC}		
o-xylene	1.83	Mackay *et al.*, 1992
m-xylene	2.22	Mackay *et al.*, 1992
p-xylene	2.31	Mackay *et al.*, 1992
Henry's Law Constant		
o-xylene	565 Pa · m^3/mol	Mackay *et al.*, 1992
m-xylene	730 Pa · m^3/mol	Mackay *et al.*, 1992
p-xylene	578 Pa · m^3/mol	Mackay *et al.*, 1992
Vapour/Particulate Phase Fraction	0.0110/0.0066	Mackay *et al.*, 1992
Vapour Pressure		
o-xylene	1170 Pa	Mackay *et al.*, 1992
m-xylene	1100 Pa	Mackay *et al.*, 1992
p-xylene	1170 Pa	Mackay *et al.*, 1992
Deposition velocity	0.015 m/s	Mackay, 1991
Air diffusivity coefficient	5×10^{-6} m^2/s	U.S. EPA, 1992
Water diffusivity coefficient	5×10^{-10} m^2/s	U.S. EPA, 1992
Solubility		
o-xylene	220,000 mg/m^3	Mackay *et al.*, 1992
m-xylene	160,000 mg/m^3	Mackay *et al.*, 1992
p-xylene	215,000 mg/m^3	Mackay *et al.*, 1992
Soil half-life	168-672 hours	Howard *et al.*, 1991
Air half-life	2.6-44 hours	Howard *et al.*, 1991
Surface water half-life	168-672 hours	Howard *et al.*, 1991
Ground water half-life	336-8640 hours	Howard *et al.*, 1991
Water-to-fish BCF	48	Mackay *et al.*, 1992
Beef transfer coefficient		
o-xylene	3.6×10^{-5} day/kg	Calculated from Travis and Arms, 1988
m-xylene	4.0×10^{-5} day/kg	Calculated from Travis and Arms, 1988
p-xylene	3.8×10^{-5} day/kg	Calculated from Travis and Arms, 1988

Table F-11 Physical and chemical properties and typical background concentrations of xylenes

Parameter		Value	Reference
Milk transfer coefficient			
	o-xylene	1.1×10^{-5} day/kg	Calculated from Travis and Arms, 1988
	m-xylene	1.3×10^{-5} day/kg	Calculated from Travis and Arms, 1988
	p-xylene	1.2×10^{-5} day/kg	Calculated from Travis and Arms, 1988
Air-to-plant (dw) BCF			
	o-xylene	1.2×10^{-5}	Calculated from Travis and Blaylock, 1992
	m-xylene	1.1×10^{-5}	Calculated from Travis and Blaylock, 1992
	p-xylene	1.3×10^{-5}	Calculated from Travis and Blaylock, 1992
Soil-to-plant (dw) BCF			
	o-xylene	0.59	Calculated from Travis and Blaylock, 1992
	m-xylene	0.55	Calculated from Travis and Blaylock, 1992
	p-xylene	0.56	Calculated from Travis and Blaylock, 1992
Background air concentration			
	o-xylene	0.0692, 0.120 μg/m^3 (Pt. Lepreau; mean, 95th percentile)	NB DOE, 1999
	m and *p*-xylenes	0.173, 0.384 μg/m^3 (Pt. Lepreau; mean, 95th percentile)	
Background water concentration		<0.5 μg/L (Canadian waters)	GC/EC/HC, 1993
Background soil concentration		0.002 μg/g soil (all land uses)	MOE, 1997

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APPENDIX G

APPLICATION OF MOEE (1997) METHODOLOGY TO THE TOXICITY ASSESSMENT OF POLYCYCLIC AROMATIC HYDROCARBONS

G-1.0 APPLICATION OF MOEE (1997) METHODOLOGY TO THE TOXICITY ASSESSMENT OF POLYCYCLIC AROMATIC HYDROCARBONS

As discussed in the MOEE (1997) document, characterization of mixtures of PAHs are generally evaluated using either: i) the *Individual PAH Model* (IPM), or ii) the *Whole Mixture Model* (WMM). The IPM model helps estimate the risk associated with the PAH fraction of a mixture by summing the risk attributable to each compound present in the mixture. The WMM model assumes that the potency of the PAH fraction of any environmental mixture of PAHs is proportional to the benzo(a)pyrene (B[a]P) content of the mixture (MOEE, 1997). It is our opinion that the WMM approach can result in conservative upper estimates of cancer risk levels (CRLs) associated with varying carcinogenic mixtures of PAHs, especially for mixtures that are considerably different in composition that those used by MOEE in the development of the methodology. While the MOEE recommends the use of the WMM method for most assessments, CANTOX ENVIRONMENTAL recommends that the IPM methodology should also be used. CANTOX ENVIRONMENTAL's opinion is that the actual cancer risk levels associated with carcinogenic PAHs need to be interpreted based on the source characteristics of the PAHs (*e.g.*, are there likely to be significant amounts of substituted PAHs present in the mixture). If the PAH mixture is relatively well defined, without the possibility of large quantities of undefined PAHs, the Individual PAH Model (IPM) - Toxic Equivalency Factor method - would provide the most realistic estimation of risks. The abbreviation B[a]P represents the benzo(a)pyrene group evaluated in the risk assessment using the individual PAH model and B[a]Ps represents the benzo(a)pyrene group evaluated using the whole mixture model for PAHs.

Without obtaining detailed knowledge of a particular PAH mixture composition, the Whole Mixture Model (WMM) can estimate cancer risks for PAH mixtures as a whole. It should be noted that several assumptions were made in the development of the WMM approach, such as:

i) PAH compositions do not vary significantly between different mixtures.
ii) The potency of a PAH mixture is relative to B[a]P.
iii) The potency of B[a]PS (whole mixture) can be a surrogate for an entire mixture.
iv) There are no antagonistic interactions between the different PAH compounds, or competitive relationships between PAHs of different potencies in their actions on tissues.

The PAH standard mixture for B[a]PS, for which the WMM assumes is representative of all environmental sources, was conservatively based on coke oven emissions data. In addition to coke oven emissions containing high concentrations of PAHs, a near complete epidemiological data set was available for this particular site, thereby allowing the estimation of cancer potency for B[a]P and the whole mixture. Potency estimates using the whole mixture (*i.e.*, B[a]PS) were found to be approximately 16-fold greater than B[a]P alone.

The IPM methodology is based on a toxic equivalency factor (TEF)/Surrogate approach. This TEF/Surrogate approach to evaluating PAH toxicity has been previously used and accepted in risk assessments presented by CANTOX ENVIRONMENTAL INC. to regulatory agencies across Canada, including Environment Canada, Health Canada, Alberta Environment, and Ontario Ministry of the Environment. It is also similar to the approaches used by BC Environment and the

Massachusetts Department of the Environment for evaluating TPH, and to approaches used to assess polychlorinated dioxins, furans and PCBs worldwide.

As data on the toxicological and physical-chemical properties of each chemical are not always available, each of the PAHs are placed into a surrogate group based on their known physical-chemical and toxicological properties. For those chemicals which the MOEE (1997) did not report toxic equivalency factors (TEFs), TEFs were calculated based on exposure limits provided by the U.S. EPA (1999), CalEPA and HC (1996). Individual TEFs were derived by assessing the relative toxicity of an individual PAH with that of its' surrogate group representative. Chemicals which did not have regulatory agency-derived exposure limits and/or TEF, were conservatively assumed to be as toxic as the surrogate chemical of concern (*i.e.*, a TEF of 1.0). For the IOL Refinery Upgrade assessment, all PAH emissions were placed into four surrogate groupings, based on their physical-chemical and toxicological properties. Table G-1 lists the PAH surrogate groupings, the chemicals of potential concern within each surrogate group, as well as the TEFs relative to the surrogate chemical.

Table G-1 PAH Surrogate Groupings and Toxic Equivalency Factors Used in the Human Health Risk Assessment

PAH Surrogate Grouping	Chemicals within Surrogate Grouping	TEFs Relative to Surrogate Chemical
Anthracene	Anthracene	1.0
Benzo[a]pyrene	2-Methylcholanthrene	1.0
	7-Methylbenz(a)anthracene	19
	Anthanthrene	0.28
	Benzo(a)anthracene	0.014
	Benzo(a)pyrene	1.0
	Benzo(b)chrysene	1.0
	Benzo(b)fluoranthene	0.11
	Benzo(b)fluorene	1.0
	Benzo(e)pyrene	0
	Benzo(g,h,i)perylene	0.012
	Benzo(k)fluoranthene	0.037
	Chrysene	0.026
	Dibenz(a,h)anthracene	1.0
	Dibenz(a,c)anthracene	1.0
	Indeno(1,2,3-cd)pyrene	0.067
	Perylene	1.0
	Phenanthrene[1]	0.00064
Naphthalene	Acenaphthylene	0.1
	Acenaphthene	1.0

PAH Surrogate Grouping	Chemicals within Surrogate Grouping	TEFs Relative to Surrogate Chemical
Fluorene	1-Methylpyrene	1.0
	2-Methyfluorene	1.0
	Benzo(a)fluorene	1.0
	Benzo(g,h,i)fluoranthene	0.32
	Fluoranthene	0.32
	Fluorene	1.0
	Phenanthrene[1]	1.0
	Pyrene	0.53
	Triphenylene	1.0

[1] As the carcinogenicity of phenanthrene is still under much debate in the literature, it was conservatively included in both the benzo[a]pyrene (carcinogen) and fluorene (non-carcinogen) TEF surrogate groups.

The IPM carcinogenic PAH group includes all PAHs in various sources of refinery stack emissions which are considered carcinogenic by MOEE (1997), HC (1996), U.S. EPA (1999) and CalEPA. It should be emphasized that some of these refineries use Bunker 'C' as a fuel source, while others (including the IOL Refinery) use fuel gas and fuel oils. Those using Bunker 'C' would have much greater emissions of PAHs because of the differences in combustion characteristics of the fuel types.

The overall concentration of the carcinogenic PAH group was calculated in terms of toxic equivalency to BaP, using toxic equivalency factors adopted by the MOEE (1997) and those calculated based on exposure limits from HC (1996), U.S. EPA (1999) and CalEPA. The non-carcinogenic PAH groups were assessed using the surrogates anthracene, naphthalene, and fluorene. The overall concentration of the non-carcinogenic PAH groups were calculated in terms of toxic equivalency using toxic equivalency factors based on exposure limits provided by HC (1996), U.S. EPA (1999) and California EPA.

As mentioned previously, in addition to the IPM methodology, the whole mixture model (WMM) was used to help characterize potential human health risks associated with PAH mixtures. It was felt that using the WMM in combination with the estimated B(a)P surrogate group air concentration would provide a range of potential human health impacts associated with carcinogenic PAHs.

G-1.1 References

CalEPA. Weighting Scheme for polycyclic aromatic hydrocarbons (PAHs). California Environmental Protection Agency (No year listed).

HC. 1996. Exposure limits for environmental toxicants. Health Canada, Ottawa.

MOEE. 1997. Scientific criteria document for multimedia standards development : polycyclic aromatic hydrocarbons (PAH). Part 1: Hazard identification and dose-response assessment. February 1997. Ontario Ministry of Environment and Energy (MOE), Toronto. PIBS 3518E. ISBN 0-7778-5914-9.

U.S. EPA. 1999. Integrated Risk Information System (IRIS). US Environmental Protection Agency (US EPA). Home Page.

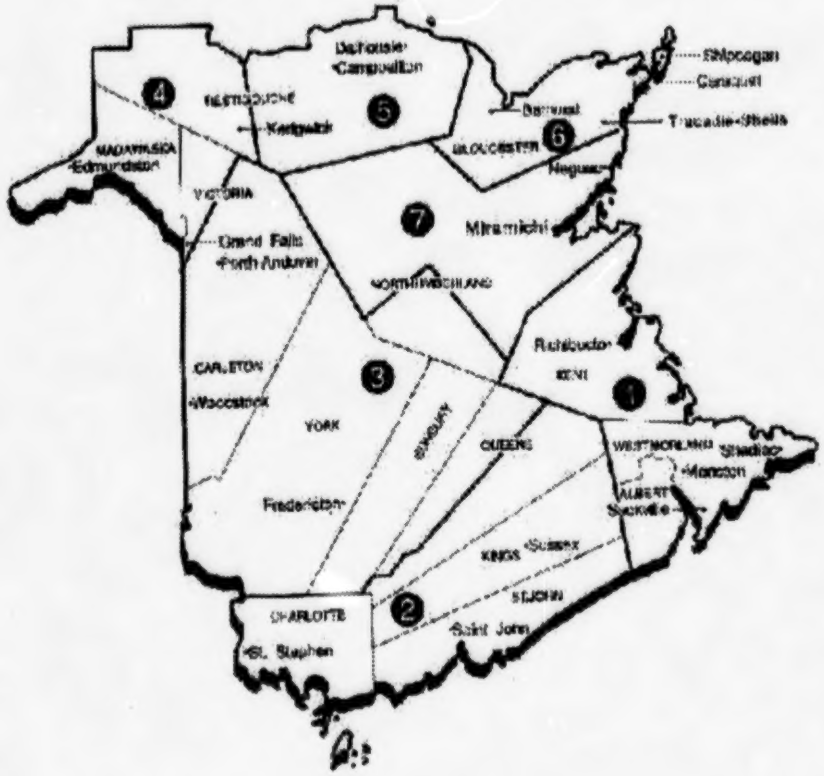
APPENDIX H

MAP OF HEALTH REGIONS IN NEW BRUNSWICK

Figure H-1 Map of Health Regions in New Brunswick

Appendix A
Map of Health Regions in New Brunswick

Health Regions


Shippagan
Caraquet
Tracadie-Sheila
Dalhousie
Campbellton
4
RESTIGOUCHE
Kedgwick
5
Bathurst
GLOUCESTER
6
Neguac
MADAWASKA
Edmundston
VICTORIA
7
Miramichi
Grand Falls
Perth Andover
NORTHUMBERLAND
Richibucto
KENT
1
CARLETON
3
Woodstock
YORK
SUNBURY
QUEENS
WESTMORLAND
Shediac
Moncton
ALBERT
Sackville
Fredericton
KINGS
Sussex
ST.JOHN
2
CHARLOTTE
Saint John
St. Stephen

APPENDIX I

QUANTITATIVE MODELLING RESULTS

BACKGROUND NON-CARCINOGENIC RISK ESTIMATES

RECEPTOR	CHEMICAL	RISK ESTIMATES s PE	s 5	s 50	s 95
FADULT.R	ANTHRACENE - IRVING OIL	1.46E-05	1.90E-07	1.22E-06	4.64E-06
FADULT.R	ETHYLBENZENE - IRVING OIL	2.55E-04	4.06E-05	8.00E-05	1.63E-04
FADULT.R	FLUORENE - IRVING OIL	1.48E-03	8.59E-05	2.77E-04	7.36E-04
FADULT.R	METHYL TERT-BUTYL ETHER - IRVING O	5.89E-02	4.18E-03	1.37E-02	3.34E-02
FADULT.R	NAPHTHALENE - IRVING OIL	1.01E-03	4.91E-05	1.79E-04	4.82E-04
FADULT.R	TOLUENE - IRVING OIL	7.17E-04	1.30E-04	2.67E-04	5.84E-04
FADULT.R	XYLENE - IRVING OIL	1.96E-03	1.82E-04	4.87E-04	1.33E-03
FCHILD.R	ANTHRACENE - IRVING OIL	3.04E-05	2.82E-07	2.19E-06	9.24E-06
FCHILD.R	ETHYLBENZENE - IRVING OIL	4.05E-04	5.59E-05	1.17E-04	2.50E-04
FCHILD.R	FLUORENE - IRVING OIL	2.95E-03	1.34E-04	4.95E-04	1.50E-03
FCHILD.R	METHYL TERT-BUTYL ETHER - IRVING O	1.21E-01	8.33E-03	2.82E-02	7.46E-02
FCHILD.R	NAPHTHALENE - IRVING OIL	1.95E-03	8.05E-05	3.14E-04	9.77E-04
FCHILD.R	TOLUENE - IRVING OIL	9.89E-04	1.64E-04	3.47E-04	7.56E-04
FCHILD.R	XYLENE - IRVING OIL	4.02E-03	3.74E-04	1.03E-03	2.92E-03
FINFANT.R	ANTHRACENE - IRVING OIL	5.44E-05	5.46E-07	4.83E-06	2.24E-05
FINFANT.R	ETHYLBENZENE - IRVING OIL	5.24E-04	5.34E-05	1.33E-04	3.25E-04
FINFANT.R	FLUORENE - IRVING OIL	5.49E-03	2.77E-04	1.14E-03	3.55E-03
FINFANT.R	METHYL TERT-BUTYL ETHER - IRVING O	8.40E-02	4.93E-03	1.73E-02	4.97E-02
FINFANT.R	NAPHTHALENE - IRVING OIL	3.63E-03	1.34E-04	7.03E-04	2.27E-03
FINFANT.R	TOLUENE - IRVING OIL	1.21E-03	1.58E-04	4.09E-04	1.08E-03
FINFANT.R	XYLENE - IRVING OIL	2.74E-03	2.18E-04	6.52E-04	1.98E-03
FTODDLER.R	ANTHRACENE - IRVING OIL	4.91E-05	4.74E-07	3.63E-06	1.57E-05
FTODDLER.R	ETHYLBENZENE - IRVING OIL	6.10E-04	7.33E-05	1.64E-04	3.77E-04
FTODDLER.R	FLUORENE - IRVING OIL	4.70E-03	2.15E-04	8.20E-04	2.47E-03
FTODDLER.R	METHYL TERT-BUTYL ETHER - IRVING O	1.69E-01	1.06E-02	3.63E-02	9.61E-02
FTODDLER.R	NAPHTHALENE - IRVING OIL	3.04E-03	1.29E-04	5.11E-04	1.56E-03
FTODDLER.R	TOLUENE - IRVING OIL	1.54E-03	2.05E-04	4.90E-04	1.19E-03
FTODDLER.R	XYLENE - IRVING OIL	5.61E-03	4.51E-04	1.32E-03	3.88E-03
FYOUTH.R	ANTHRACENE - IRVING OIL	1.80E-05	1.77E-07	1.38E-06	5.76E-06
FYOUTH.R	ETHYLBENZENE - IRVING OIL	2.54E-04	3.51E-05	7.24E-05	1.47E-04
FYOUTH.R	FLUORENE - IRVING OIL	1.82E-03	9.20E-05	3.22E-04	8.94E-04
FYOUTH.R	METHYL TERT-BUTYL ETHER - IRVING O	6.36E-02	4.69E-03	1.47E-02	3.56E-02
FYOUTH.R	NAPHTHALENE - IRVING OIL	1.24E-03	5.15E-05	2.08E-04	5.90E-04
FYOUTH.R	TOLUENE - IRVING OIL	6.52E-04	1.03E-04	2.25E-04	4.89E-04
FYOUTH.R	XYLENE - IRVING OIL	2.11E-03	2.02E-04	5.37E-04	1.44E-03

BACKGROUND CARCINOGENIC RISK ESTIMATES

			RISK ESTIMATES			
RECEPTOR	CHEMICAL	s PE	s 5	s 50	s 95	
INCREMENTAL LIFETIME CANCER RISK (ILCR)						
			Cancer Risk Level			**Endpoint**
BENZENE	LIFETIME COMPOSITE	6.97E-06	1.37E-06	2.60E-06	5.04E-06	Leukemia
B[A]P dermal	LIFETIME COMPOSITE	9.62E-05	1.83E-06	1.88E-05	6.16E-05	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	4.02E-06	6.06E-07	1.43E-06	3.26E-06	lung tumours
B[A]P oral	LIFETIME COMPOSITE	4.26E-06	3.31E-08	3.87E-07	1.54E-06	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	5.24E-05	8.66E-06	2.46E-05	4.96E-05	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	5.72E-06	4.25E-07	1.11E-06	4.70E-06	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	2.25E-06	1.35E-07	4.74E-07	1.29E-06	stomach tumours
BUTADIENE	LIFETIME COMPOSITE	7.46E-05	7.34E-07	5.82E-06	4.57E-05	Lung alveolar and bronchiolar neoplasms
CROTONALDEHYDI	LIFETIME COMPOSITE	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Liver tumours

EXISTING AMBIENT SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT FOREST HILL, SAINT JOHN

		RISK ESTIMATES			
RECEPTOR	CHEMICAL	s PE	s 5	s 50	s 95
FADULT.R	ANTHRACENE	1.29E-07	6.76E-09	1.54E-08	4.13E-08
FADULT.R	ETHYLBENZENE	2.54E-03	1.42E-04	3.28E-04	8.63E-04
FADULT.R	FLUORENE	2.87E-04	2.98E-05	5.72E-05	1.14E-04
FADULT.R	METHYL TERT-BUTYL ETHER	6.52E-01	1.93E-02	1.79E-01	4.25E-01
FADULT.R	NAPHTHALENE	4.42E-04	3.41E-06	4.09E-05	4.68E-04
FADULT.R	TOLUENE	1.86E-02	1.01E-04	5.07E-04	4.26E-03
FADULT.R	XYLENE	1.89E-02	9.13E-04	3.15E-03	1.10E-02
FCHILD.R	ANTHRACENE	2.69E-07	1.24E-08	3.02E-08	8.73E-08
FCHILD.R	ETHYLBENZENE	4.69E-03	2.11E-04	5.39E-04	1.59E-03
FCHILD.R	FLUORENE	5.72E-04	5.69E-05	1.14E-04	2.41E-04
FCHILD.R	METHYL TERT-BUTYL ETHER	1.54E+00	3.63E-02	3.72E-01	9.81E-01
FCHILD.R	NAPHTHALENE	8.99E-04	7.74E-06	8.68E-05	9.80E-04
FCHILD.R	TOLUENE	3.56E-02	1.56E-04	9.39E-04	8.01E-03
FCHILD.R	XYLENE	3.88E-02	1.95E-03	6.75E-03	2.40E-02
FINFANT.R	ANTHRACENE	4.69E-07	1.40E-08	5.12E-08	1.85E-07
FINFANT.R	ETHYLBENZENE	7.43E-03	2.14E-04	6.57E-04	2.19E-03
FINFANT.R	FLUORENE	9.20E-04	5.00E-05	1.38E-04	3.85E-04
FINFANT.R	METHYL TERT-BUTYL ETHER	1.01E+00	2.50E-02	2.49E-01	6.97E-01
FINFANT.R	NAPHTHALENE	8.42E-04	4.90E-06	6.22E-05	7.27E-04
FINFANT.R	TOLUENE	6.77E-02	1.97E-04	1.51E-03	1.54E-02
FINFANT.R	XYLENE	2.84E-02	1.16E-03	4.38E-03	1.63E-02
FTODDLER.R	ANTHRACENE	4.31E-07	1.77E-08	4.62E-08	1.37E-07
FTODDLER.R	ETHYLBENZENE	7.10E-03	2.73E-04	7.71E-04	2.36E-03
FTODDLER.R	FLUORENE	8.77E-04	7.66E-05	1.61E-04	3.53E-04
FTODDLER.R	METHYL TERT-BUTYL ETHER	2.31E+00	5.16E-02	4.86E-01	1.30E+00
FTODDLER.R	NAPHTHALENE	1.28E-03	8.45E-06	1.11E-04	1.36E-03
FTODDLER.R	TOLUENE	5.53E-02	2.10E-04	1.42E-03	1.28E-02
FTODDLER.R	XYLENE	5.44E-02	2.30E-03	8.74E-03	3.23E-02
FYOUTH.R	ANTHRACENE	1.59E-07	7.45E-09	1.74E-08	5.03E-08
FYOUTH.R	ETHYLBENZENE	2.91E-03	1.30E-04	3.22E-04	8.93E-04
FYOUTH.R	FLUORENE	3.43E-04	3.36E-05	6.38E-05	1.29E-04
FYOUTH.R	METHYL TERT-BUTYL ETHER	7.04E-01	2.13E-02	1.93E-01	4.50E-01
FYOUTH.R	NAPHTHALENE	4.92E-04	3.96E-06	4.46E-05	4.94E-04
FYOUTH.R	TOLUENE	2.30E-02	9.87E-05	5.61E-04	4.69E-03
FYOUTH.R	XYLENE	2.05E-02	1.02E-03	3.48E-03	1.19E-02

EXISTING AMBIENT SCENARIO

CARCINOGENIC RISK ESTIMATES AT FOREST HILL, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
		Cancer Risk Level				**Endpoint**
BENZENE	LIFETIME COMPOSITE	8.92E-05	2.84E-06	8.05E-06	2.50E-05	Leukemia
B[A]P dermal	LIFETIME COMPOSITE	7.50E-07	2.54E-08	1.17E-07	3.61E-07	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	4.61E-06	1.28E-06	2.32E-06	4.23E-06	lung tumours
B[A]P oral	LIFETIME COMPOSITE	3.89E-08	6.31E-10	3.03E-09	1.03E-08	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	3.30E-06	9.87E-08	4.68E-07	1.52E-06	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	1.93E-05	4.47E-06	8.88E-06	1.75E-05	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	1.66E-07	2.34E-09	1.18E-08	4.23E-08	stomach tumours
BUTADIENE	LIFETIME COMPOSITE	8.15E-04	7.87E-06	3.70E-05	1.82E-04	Lung alveolar and bronchiolar neopl
ALDEHYDE GROUP	LIFETIME COMPOSITE	5.39E-05	8.76E-07	4.22E-06	1.79E-05	Liver tumours

EXISTING STUDY AREA SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT FOREST HILL, SAINT JOHN

RECEPTOR	CHEMICAL	RISK ESTIMATES s PE	s 5	s 50	s 95
FADULT.R	ANTHRACENE	2.57E-09	3.39E-10	3.49E-10	8.22E-10
FADULT.R	FLUORENE	5.71E-06	1.49E-06	1.30E-06	2.27E-06
FADULT.R	NAPHTHALENE	8.80E-06	1.71E-07	9.27E-07	9.32E-06
FCHILD.R	ANTHRACENE	5.36E-09	6.21E-10	6.85E-10	1.74E-09
FCHILD.R	FLUORENE	1.14E-05	2.85E-06	2.58E-06	4.80E-06
FCHILD.R	NAPHTHALENE	1.79E-05	3.88E-07	1.97E-06	1.95E-05
FINFANT.R	ANTHRACENE	9.34E-09	7.01E-10	1.16E-09	3.68E-09
FINFANT.R	FLUORENE	1.83E-05	2.50E-06	3.13E-06	7.67E-06
FINFANT.R	NAPHTHALENE	1.68E-05	2.45E-07	1.41E-06	1.45E-05
FTODDLER.R	ANTHRACENE	8.58E-09	8.87E-10	1.05E-09	2.73E-09
FTODDLER.R	FLUORENE	1.75E-05	3.84E-06	3.65E-06	7.03E-06
FTODDLER.R	NAPHTHALENE	2.55E-05	4.23E-07	2.52E-06	2.71E-05
FYOUTH.R	ANTHRACENE	3.17E-09	3.73E-10	3.94E-10	1.00E-09
FYOUTH.R	FLUORENE	6.83E-06	1.68E-06	1.45E-06	2.57E-06
FYOUTH.R	NAPHTHALENE	9.80E-06	1.98E-07	1.01E-06	9.84E-06

EXISTING STUDY AREA SCENARIO

CARCINOGENIC RISK ESTIMATES AT FOREST HILL, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
			Cancer Risk Level			Endpoint
B[A]P dermal	LIFETIME COMPOSITE	1.49E-08	1.27E-09	2.65E-09	7.19E-09	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	9.19E-08	6.43E-08	5.27E-08	8.41E-08	lung tumours
B[A]P oral	LIFETIME COMPOSITE	7.74E-10	3.16E-11	6.88E-11	2.06E-10	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	6.57E-08	4.94E-09	1.06E-08	3.02E-08	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	3.83E-07	2.24E-07	2.01E-07	3.48E-07	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	3.30E-09	1.17E-10	2.68E-10	8.42E-10	stomach tumours

FUTURE STUDY AREA SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT FOREST HILL, SAINT JOHN

RECEPTOR	CHEMICAL	RISK ESTIMATES s PE	s 5	s 50	s 95
FADULT.R	ANTHRACENE	3.21E-09	4.24E-10	4.37E-10	1.03E-09
FADULT.R	FLUORENE	7.15E-06	1.87E-06	1.62E-06	2.84E-06
FADULT.R	NAPHTHALENE	1.10E-05	2.14E-07	1.16E-06	1.17E-05
FCHILD.R	ANTHRACENE	6.70E-09	7.77E-10	8.56E-10	2.17E-09
FCHILD.R	FLUORENE	1.42E-05	3.57E-06	3.23E-06	6.00E-06
FCHILD.R	NAPHTHALENE	2.24E-05	4.65E-07	2.46E-06	2.44E-05
FINFANT.R	ANTHRACENE	1.17E-08	8.77E-10	1.45E-09	4.61E-09
FINFANT.R	FLUORENE	2.29E-05	3.13E-06	3.91E-06	9.59E-06
FINFANT.R	NAPHTHALENE	2.10E-05	3.07E-07	1.76E-06	1.81E-05
FTODDLER.R	ANTHRACENE	1.07E-08	1.11E-09	1.31E-09	3.41E-09
FTODDLER.R	FLUORENE	2.18E-05	4.80E-06	4.56E-06	8.79E-06
FTODDLER.R	NAPHTHALENE	3.19E-05	5.29E-07	3.15E-06	3.39E-05
FYOUTH.R	ANTHRACENE	3.96E-09	4.67E-10	4.93E-10	1.25E-09
FYOUTH.R	FLUORENE	8.54E-06	2.11E-06	1.81E-06	3.21E-06
FYOUTH.R	NAPHTHALENE	1.23E-05	2.48E-07	1.26E-06	1.23E-05

FUTURE STUDY AREA SCENARIO

CARCINOGENIC RISK ESTIMATES AT FOREST HILL, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
			Cancer Risk Level			Endpoint
B[A]P dermal	LIFETIME COMPOSITE	1.87E-08	1.59E-09	3.32E-09	5.99E-09	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	1.15E-07	8.04E-08	6.59E-08	1.05E-07	lung tumours
B[A]P oral	LIFETIME COMPOSITE	9.68E-10	3.95E-11	8.60E-11	2.58E-10	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	8.22E-08	6.18E-09	1.33E-08	3.77E-08	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	4.80E-07	2.80E-07	2.52E-07	4.36E-07	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	4.13E-09	1.47E-10	3.35E-10	1.05E-09	stomach tumours

EXISTING STUDY AREA SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT SILVER FALLS, SAINT JOHN

		RISK ESTIMATES			
RECEPTOR	**CHEMICAL**	**s PE**	**s 5**	**s 50**	**s 95**
FADULT.R	ANTHRACENE	4.49E-09	5.92E-10	6.10E-10	1.44E-09
FADULT.R	FLUORENE	9.98E-06	2.61E-06	2.27E-06	3.97E-06
FADULT.R	NAPHTHALENE	1.54E-05	2.98E-07	1.62E-06	1.63E-05
FCHILD.R	ANTHRACENE	9.36E-09	1.09E-09	1.20E-09	3.04E-09
FCHILD.R	FLUORENE	1.99E-05	4.98E-06	4.52E-06	8.38E-06
FCHILD.R	NAPHTHALENE	3.13E-05	6.77E-07	3.44E-06	3.41E-05
FINFANT.R	ANTHRACENE	1.63E-08	1.23E-09	2.03E-09	6.44E-09
FINFANT.R	FLUORENE	3.20E-05	4.38E-06	5.47E-06	1.34E-05
FINFANT.R	NAPHTHALENE	2.93E-05	4.29E-07	2.46E-06	2.53E-05
FTODDLER.R	ANTHRACENE	1.50E-08	1.55E-09	1.83E-09	4.77E-09
FTODDLER.R	FLUORENE	3.06E-05	6.70E-06	6.38E-06	1.23E-05
FTODDLER.R	NAPHTHALENE	4.45E-05	7.40E-07	4.40E-06	4.73E-05
FYOUTH.R	ANTHRACENE	5.53E-09	6.52E-10	6.89E-10	1.75E-09
FYOUTH.R	FLUORENE	1.19E-05	2.94E-06	2.53E-06	4.49E-06
FYOUTH.R	NAPHTHALENE	1.71E-05	3.47E-07	1.77E-06	1.72E-05

EXISTING STUDY AREA SCENARIO

CARCINOGENIC RISK ESTIMATES AT SILVER FALLS, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
			Cancer Risk Level			**Endpoint**
B[A]P dermal	LIFETIME COMPOSITE	2.61E-08	2.23E-09	4.64E-09	1.26E-08	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	1.61E-07	1.12E-07	9.20E-08	1.47E-07	lung tumours
B[A]P oral	LIFETIME COMPOSITE	1.35E-09	5.52E-11	1.20E-10	3.60E-10	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	1.15E-07	8.64E-09	1.85E-08	5.27E-08	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	6.70E-07	3.91E-07	3.52E-07	6.09E-07	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	5.77E-09	2.05E-10	4.69E-10	1.47E-09	stomach tumours

FUTURE STUDY AREA SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT SILVER FALLS, SAINT JOHN

RECEPTOR	CHEMICAL	RISK ESTIMATES s PE	s 5	s 50	s 95
FADULT.R	ANTHRACENE	6.44E-09	8.49E-10	8.76E-10	2.06E-09
FADULT.R	FLUORENE	1.43E-05	3.74E-06	3.25E-06	5.69E-06
FADULT.R	NAPHTHALENE	2.21E-05	4.29E-07	2.33E-06	2.34E-05
FCHILD.R	ANTHRACENE	1.34E-08	1.56E-09	1.72E-09	4.36E-09
FCHILD.R	FLUORENE	2.86E-05	7.15E-06	6.48E-06	1.20E-05
FCHILD.R	NAPHTHALENE	4.49E-05	9.73E-07	4.94E-06	4.89E-05
FINFANT.R	ANTHRACENE	2.34E-08	1.76E-09	2.91E-09	9.24E-09
FINFANT.R	FLUORENE	4.60E-05	6.28E-06	7.85E-06	1.92E-05
FINFANT.R	NAPHTHALENE	4.21E-05	6.16E-07	3.54E-06	3.63E-05
FTODDLER.R	ANTHRACENE	2.15E-08	2.22E-09	2.63E-09	6.84E-09
FTODDLER.R	FLUORENE	4.38E-05	9.63E-06	9.15E-06	1.76E-05
FTODDLER.R	NAPHTHALENE	6.39E-05	1.06E-06	6.31E-06	6.79E-05
FYOUTH.R	ANTHRACENE	7.94E-09	9.36E-10	9.89E-10	2.51E-09
FYOUTH.R	FLUORENE	1.71E-05	4.22E-06	3.63E-06	6.44E-06
FYOUTH.R	NAPHTHALENE	2.46E-05	4.98E-07	2.54E-06	2.47E-05

FUTURE STUDY AREA SCENARIO

CARCINOGENIC RISK ESTIMATES AT SILVER FALLS, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
			Cancer Risk Level			Endpoint
B[A]P dermal	LIFETIME COMPOSITE	3.75E-08	3.20E-09	6.66E-09	1.80E-08	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	2.30E-07	1.61E-07	1.32E-07	2.11E-07	lung tumours
B[A]P oral	LIFETIME COMPOSITE	1.94E-09	7.93E-11	1.73E-10	5.17E-10	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	1.65E-07	1.24E-08	2.66E-08	7.57E-08	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	9.62E-07	5.62E-07	5.05E-07	8.74E-07	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	8.29E-09	2.94E-10	6.73E-10	2.11E-09	stomach tumours

EXISTING STUDY SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT CHAMPLAIN HEIGHTS, SAINT JOHN

		RISK ESTIMATES			
RECEPTOR	**CHEMICAL**	**s PE**	**s 5**	**s 50**	**s 95**
FADULT.R	ANTHRACENE	7.69E-09	1.01E-09	1.04E-09	2.46E-09
FADULT.R	FLUORENE	1.71E-05	4.47E-06	3.88E-06	6.79E-06
FADULT.R	NAPHTHALENE	2.63E-05	5.11E-07	2.77E-06	2.79E-05
FCHILD.R	ANTHRACENE	1.60E-08	1.86E-09	2.05E-09	5.20E-09
FCHILD.R	FLUORENE	3.41E-05	8.53E-06	7.73E-06	1.44E-05
FCHILD.R	NAPHTHALENE	5.36E-05	1.16E-06	5.89E-06	5.84E-05
FINFANT.R	ANTHRACENE	2.79E-08	2.10E-09	3.47E-09	1.10E-08
FINFANT.R	FLUORENE	5.48E-05	7.50E-06	9.36E-06	2.29E-05
FINFANT.R	NAPHTHALENE	5.02E-05	7.35E-07	4.22E-06	4.33E-05
FTODDLER.R	ANTHRACENE	2.57E-08	2.65E-09	3.13E-09	8.16E-09
FTODDLER.R	FLUORENE	5.23E-05	1.15E-05	1.09E-05	2.10E-05
FTODDLER.R	NAPHTHALENE	7.63E-05	1.27E-06	7.53E-06	8.10E-05
FYOUTH.R	ANTHRACENE	9.48E-09	1.12E-09	1.18E-09	3.00E-09
FYOUTH.R	FLUORENE	2.04E-05	5.04E-06	4.33E-06	7.69E-06
FYOUTH.R	NAPHTHALENE	2.93E-05	5.94E-07	3.03E-06	2.94E-05

EXISTING STUDY SCENARIO

CARCINOGENIC RISK ESTIMATES AT CHAMPLAIN HEIGHTS, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
			Cancer Risk Level			Endpoint
B[A]P dermal	LIFETIME COMPOSITE	4.47E-08	3.81E-09	7.94E-09	2.15E-08	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	2.75E-07	1.92E-07	1.58E-07	2.52E-07	lung tumours
B[A]P oral	LIFETIME COMPOSITE	2.32E-09	9.46E-11	2.06E-10	6.16E-10	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	1.97E-07	1.48E-08	3.18E-08	9.03E-08	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	1.15E-06	6.70E-07	6.02E-07	1.04E-06	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	9.89E-09	3.51E-10	8.03E-10	2.52E-09	stomach tumours

FUTURE STUDY AREA SCENARIO

NON-CARCINOGENIC RISK ESTIMATES AT CHAMPLAIN HEIGHTS, SAINT JOHN

		RISK ESTIMATES			
RECEPTOR	**CHEMICAL**	**s PE**	**s 5**	**s 50**	**s 95**
FADULT.R	ANTHRACENE	8.98E-09	1.18E-09	1.22E-09	2.87E-09
FADULT.R	FLUORENE	2.00E-05	5.22E-06	4.53E-06	7.93E-06
FADULT.R	NAPHTHALENE	3.08E-05	5.97E-07	3.24E-06	3.26E-05
FCHILD.R	ANTHRACENE	1.87E-08	2.17E-09	2.39E-09	6.07E-09
FCHILD.R	FLUORENE	3.98E-05	9.96E-06	9.03E-06	1.68E-05
FCHILD.R	NAPHTHALENE	6.26E-05	1.35E-06	6.88E-06	6.82E-05
FINFANT.R	ANTHRACENE	3.26E-08	2.45E-09	4.06E-09	1.29E-08
FINFANT.R	FLUORENE	6.40E-05	8.75E-06	1.09E-05	2.68E-05
FINFANT.R	NAPHTHALENE	5.86E-05	8.58E-07	4.93E-06	5.06E-05
FTODDLER.R	ANTHRACENE	3.00E-08	3.10E-09	3.66E-09	9.53E-09
FTODDLER.R	FLUORENE	6.10E-05	1.34E-05	1.28E-05	2.46E-05
FTODDLER.R	NAPHTHALENE	8.91E-05	1.48E-06	8.79E-06	9.46E-05
FYOUTH.R	ANTHRACENE	1.11E-08	1.30E-09	1.38E-09	3.50E-09
FYOUTH.R	FLUORENE	2.39E-05	5.88E-06	5.05E-06	8.98E-06
FYOUTH.R	NAPHTHALENE	3.42E-05	6.93E-07	3.53E-06	3.44E-05

FUTURE STUDY AREA SCENARIO

CARCINOGENIC RISK ESTIMATES AT CHAMPLAIN HEIGHTS, SAINT JOHN

INCREMENTAL LIFETIME CANCER RISK (ILCR)

CHEMICAL	RECEPTOR	s PE	s 5	s 50	s 95	
			Cancer Risk Level			**Endpoint**
B[A]P dermal	LIFETIME COMPOSITE	5.22E-08	4.45E-09	9.27E-09	2.51E-08	skin tumours
B[A]P inhalation	LIFETIME COMPOSITE	3.21E-07	2.25E-07	1.84E-07	2.94E-07	lung tumours
B[A]P oral	LIFETIME COMPOSITE	2.71E-09	1.10E-10	2.40E-10	7.20E-10	stomach tumours
B[A]Ps dermal	LIFETIME COMPOSITE	2.30E-07	1.73E-08	3.71E-08	1.05E-07	skin tumours
B[A]Ps inhalation	LIFETIME COMPOSITE	1.34E-06	7.82E-07	7.03E-07	1.22E-06	lung tumours
B[A]Ps oral	LIFETIME COMPOSITE	1.15E-08	4.10E-10	9.37E-10	2.94E-09	stomach tumours

APPENDIX J

CRUDE INCIDENCE RATES

Table J-1 **Crude Incidence Rates per 100,000 population for the Leading 25 Cancer Diagnoses, 1988-1997**

Cancer Site	Incidence in Saint John /100,000		Incidence in Fredericton /100,000	
	Males	Females	Males	Females
Oral	180	90	110	40
Esophagus	70	40	80	30
Stomach	160	100	120	70
Colorectal	760	650	740	630
Liver	40	0	20	20
Pancreas	120	120	100	100
Larynx	120	10	80	20
Lung	1340	710	820	400
Skin	130	130	140	130
Connective Tissue	20	20	20	20
Breast	0	1260	0	1570
Cervix	0	130	0	70
Uterus	0	260	0	260
Ovary	0	180	0	200
Prostate	1670	0	1430	0
Bladder	360	150	330	120
Kidney	210	120	160	120
Brain	70	60	130	80
Thyroid	30	60	20	60
Hodgkins Disease	10	20	30	30
Non-Hodgkins Lymphoma	190	190	210	140
Multiple Myeloma	60	40	90	50
Leukemia	110	80	80	90
All Sites	6030	4770	5060	4610

Note: These data were obtained from the NB Provincial Epidemiology Service

APPENDIX K

CRUDE MORTALITY RATES

Table K-1 Crude Mortality Rates per 100,000 population for the Leading 25 Cancer Diagnoses 1988-1997

Cancer Site	Incidence in Saint John /100,000		Incidence in Fredericton /100,000	
	Males	Females	Males	Females
Oral	60	20	20	10
Esophagus	90	30	90	20
Stomach	80	80	80	50
Colorectal	210	200	200	210
Liver	50	20	50	20
Pancreas	130	130	90	100
Larynx	50	0	20	0
Lung	1100	610	650	280
Skin	30	30	40	10
Connective Tissue	0	10	20	10
Breast	10	440	0	430
Cervix	0	40	0	30
Uterus	0	40	0	50
Ovary	0	130	0	110
Prostate	280	0	220	0
Bladder	90	30	110	50
Kidney	70	60	50	50
Brain	50	40	80	40
Thyroid	0	0	0	0
Hodgkins Disease	10	10	0	10
Non-Hodgkins Lymphoma	110	90	100	90
Multiple Myeloma	60	20	60	50
Leukemia	90	50	60	80
All Sites	2940	2450	2280	2100

Note: These data were obtained from the NB Provincial Epidemiology Service

APPENDIX L

OUTLINE OF A COMMUNITY HEALTH PROGRAM FOR SAINT JOHN

L-1.0 Outline of a Community Health Program for Saint John

The Community Health Program concept as outlined herein depends on balanced, equitable relationships between groups and individuals who are stakeholders in the health of the Saint John community. Adaptations of the concept to other issues, such as the environment, are readily achievable; however, the information presented focusses solely on the issue of community health.

L-1.1 Why are Balanced Stakeholder Inter-Relationships Important?

There are a number of stakeholders affected by the operation of any type of facility or group of facilities, irrespective of whether such facilities are in the private or public sectors. For example, the operating facilities could be an industrial plant, a sewage treatment plant, or electrical power generating facility.

The stakeholders that are affected by such facilities or activities fall into three broad focus areas:

- Environment – including those concerned about wildlife, habitat loss, ecosystem health;
- Community – including those concerned about health/safety, air quality, sensitive individuals, quality of life; or
- Facility Operations – including those concerned about the balance between operating efficiency, shareholder, environmental stewardship.

Successful recognition and resolution of issues and concerns that stakeholders have about community health depends on achieving and maintaining a balance of their inter-relationships. Balancing stakeholder inter-relationships means that stakeholder issues and concerns are recognized and addressed in an equitable manner.

It is important to recognize that imbalance in these inter-relationships leads to confrontation, disruptions and mistrust amongst all stakeholder groups. These imbalances are associated with real costs to all stakeholders, in social and economic terms.

In Saint John, imbalances exist between environment, community and facility stakeholders. These imbalances are a major source of confrontation between various stakeholder groups within the Saint John community. Such result in the non-productive expenditure of large amounts of energy and resources, and diminish the benefits and gains that are available to all stakeholders.

Balanced inter-relationships

- mean stakeholders know what to expect and what is expected;
- will save significant social and economic costs;
- make the environment more sustainable;
- improve the overall quality of life in the community;
- enable the facilities to be more productive and profitable; and
- produce positive gains for all stakeholders.

Clearly, achieving such goals would be highly desirable for all stakeholder groups: the environment, the community and facility operations.

The obvious question is: How can such a balance in stakeholder inter-relationships be achieved and maintained?

L-1.2 Framework for Balancing Stakeholder Inter-Relationships

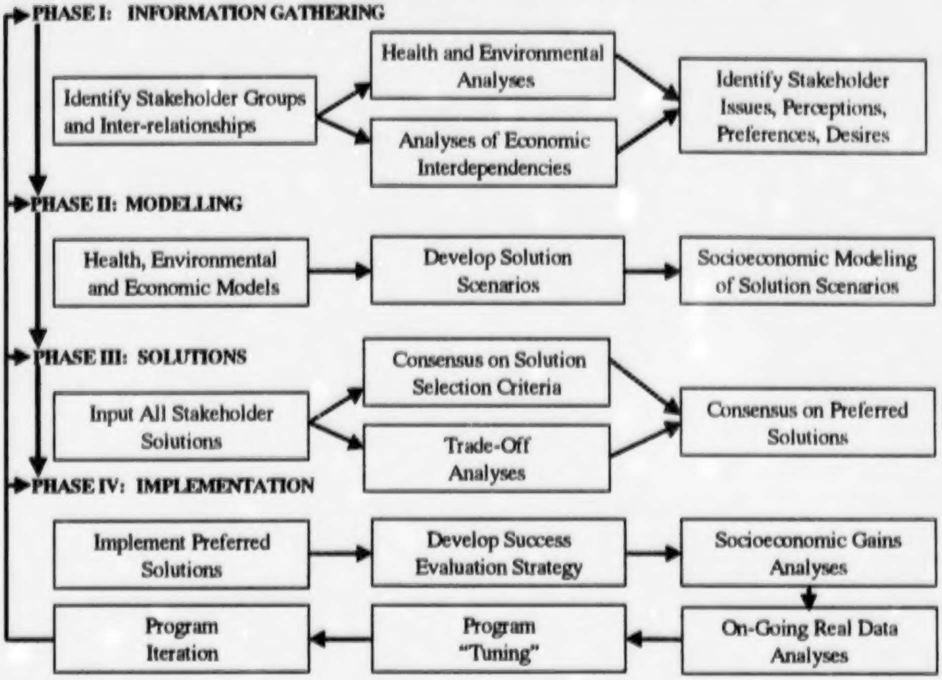
Establishing balance in stakeholder inter-relationships in Saint John, or elsewhere, depends on a workable process for addressing the issues related to community health in a timely, and equitable manner. There must be both the perception and realization that stakeholders have equal voices in the consideration of their concerns about the health of people in the community. These goals are best achieved by providing a means of open, unrestricted communication between stakeholders. This sounds simple enough, but experience shows the achievement of these goals require a process that is agreeable to all stakeholders, and through which they can equally participate.

Figure L-1 outlines a framework for such a process for in the Saint John region.

The process outlined starts with the identification of the various individuals and groups that are concerned about community health in the Saint John region. A forum is then established, through a Community Health Committee (CHC), that facilitates open and equitable communication between stakeholders. The form, format and *modus operandi* of the CHC must be established jointly by the stakeholders. This is their committee, and of the CHC must be agreed to by consensus of the stakeholders.

Next, agreement between stakeholders is required on the assessment and evaluation criteria. One of the outcomes of these stakeholder undertakings is the assembly of various models that describe the inter-relationships between stakeholders in Saint John. These models enable evaluation of various through the prediction of outcomes from implementation of specific. From these predictions a consensus-building process leads to the prioritisation and implementation of appropriate actions, undertakings and interventions to improve the health of people within the Saint John region. The later stages of the process focus on the adoption of tools for measuring risk/benefit gains by stakeholders based on the implemented interventions and undertakings. Finally, the progress towards achieving these gains is measured, and the process is modified or adjusted as required to deliver equitable gains to all Saint John's stakeholders into the future.

FIGURE L-1: PROCESS FOR ACHIEVING STAKEHOLDER BALANCE


PHASE I: INFORMATION GATHERING
Identify Stakeholder Groups and Inter-relationships
Health and Environmental Analyses
Analyses of Economic Interdependencies
Identify Stakeholder Issues, Perceptions, Preferences, Desires
PHASE II: MODELLING
Health, Environmental and Economic Models
Develop Solution Scenarios
Socioeconomic Modeling of Solution Scenarios
PHASE III: SOLUTIONS
Input All Stakeholder Solutions
Consensus on Solution Selection Criteria
Trade-Off Analyses
Consensus on Preferred Solutions
PHASE IV: IMPLEMENTATION
Implement Preferred Solutions
Develop Success Evaluation Strategy
Socioeconomic Gains Analyses
On-Going Real Data Analyses
Program "Tuning"
Program Iteration

L-1.3 Stakeholder Balance / Community Health

As indicated previously, the current discussion focusses on the health of people in the community through the initiation of a Community Health Program. Once such a program is underway, it will be issues identified by the stakeholders in the region.

The combination of open, equitable communications and the application of the Public Health Paradigm are major components of Community Health Programs. The Public Health Paradigm depends on the best available environmental, toxicological and medical sciences to:

- establish community health priorities;
- identify causal linkages in human disease etiologies;
- develop appropriate interventions to address the community health issues; and
- to conduct iterative evaluations to optimize the effectiveness of the intervention programs.

With this information, the Community Health Committee can prioritize and deliver appropriate initiatives to address the health issues and concerns of people in the community. Through the this process the stakeholders in the community are empowered to take an active role in the improvement of their health. The root of the success of these programs lies in the integration of best available science from various disciplines with the stakeholder balance process as outlined in Figure L-1. The key to the stakeholder balance process is the facilitation of open communication and cooperation between people in all sectors of the community, including the general public, various levels of government, and industry.

To be successful, the process must be continuous and be adaptable over time to changing conditions and factors in the community; thus are truly Community Health Programs, not simply one time projects that do not provide continuing follow-up.

L-1.4 What is the Public Health Paradigm?

The public health paradigm provides a systematic basis for rational analysis of public health issues, leading to the development and implementation of appropriate management initiatives aimed at protecting and improving the health of the public. Such a framework forms the basis of the health management approach recently proposed by Health Canada to address public health issues. This approach is becoming part of the Canadian Federal Government's health legislation, and these steps will become common practice over the next few years for the improvement of the health of communities.

The creation of a framework referred to as the public health paradigm for the management of disease is historically grounded. The paradigm has been tested and applied for over two hundred years (Baller *et al.*, 1991; Carlo *et al.*, 1995), and its concepts successfully applied to develop and implement various types of interventions known to have meaningful impacts on the reduction of disease and improvement of health (Baller *et al.*, 1991; Carlo *et al.*, 1995; Carlo, 1998; Carlo *et al.*, 1998).

The paradigm assumes that (1) public health problems are shared across the community, and (2) the path toward solution reflects the interest of the community as a whole. As such, possible causes of measurable health effects and the interventions to correct them, can not be examined in isolation. The definition of health issues and their resolution must address the larger context of exposures to a population from a wide range of sources and types of substances present in the environment within the community.

The correction of problems that effect public health is fundamentally dependant on exposure based, and disease based interventions. The public health paradigm does not necessitate the development of unequivocal proof of causal linkages between exposure and disease to affect an improvement public health.

The framework and its application sets priorities among the myriad of public health issues. The disease etiology must be sufficiently understood to support effective intervention. The framework should provide the necessary information to develop and implement appropriate management strategies, which in turn, will correct health problems, and deliver an improvement in public health.

The Public Health Paradigm is based on the following series of questions, formulated to assess the risks of adverse public health concerns, and help delineate causal factors:

i) Are there measurable adverse public health outcomes or conditions in the community that are different in type or magnitude than other nearby communities?

ii) For those health outcomes that are unique or notable in the community:
   - what is the magnitude of these effects?
   - where are the effects observed?
   - who in the population is affected?
   - when are these people affected?
   - what are the etiologies and causal factors of the diseases observed?

iii) If some types of interventions are warranted to improve public health in the community, what management strategies are available that are considered appropriate for accomplishing the desired improvement in public health?

iv) Which interventions and procedures will be implemented in the Community Health Program, in what sequence, and how can their success be measured and monitored?

The best available medical, toxicological and epidemiological sciences must be applied to addressing the questions. Otherwise, there would not be adequate confidence or certainty in the answers to the questions.

Should the answer to question number i) indicate that there are not measurable differences in the health outcomes or conditions between two communities, does not mean there are not concerns in the community about their health. All such a result would signify is that there are not unique health outcomes or conditions in one community compared to the other. Such a result would indicate it is unlikely that improvements in the health of the community would be achieved by investigating unique characteristics of the community (*e.g.*, investigation of emissions from various sources). However, various interventions or management programs can still be developed to address health concerns that are not unique to a particular community. Important improvements in such public health issues can still be achieved, although not directly related to some unique factor within the community.

L-1.5 Integration of Health Risk and Public Health Assessments into a Community Health Program

Human health risk assessments and a public health assessments, such as those partially completed in Saint John, are two complementary and critical components of a Community Health Program that provide the information needed for the application of the public health paradigm. Health risk assessment methods provide a tool for evaluating potential health impacts from specific activities or operations within a community. Public Health Assessments focus on the delineation of the health status or disease incidence in the community, and an in-depth examination of the etiology of diseases identified. Health risk and public health assessments can be combined to provide greater insight into the possible causal factors of health outcomes in the Saint John community.

Health Risk Assessment methods provide reasonable estimates of the risks of adverse health effects in a community from a single, or any number of specified sources of environmental input of substances (air, aqueous effluents, *etc.*). The health risk assessment methods use mathematical models to separate evaluation of specific sources of potential exposure to people in the community.

Although they provide very useful information on existing facilities, a primary strength of risk assessment methods is their ability, through the use of predictive models, to provide prospective estimates of potential risks from specific exposures in the future, before a facility is operational and is actually releasing substances into the environment. This information is valuable in problem solving during the design of facilities, because it enables the analysis and development of appropriate risk management options to ensure a specific facility does not produce unacceptable impacts on human health or the environment after it is operational.

Since health risk assessments are based on mathematical modelling techniques, the results are amenable to sensitivity analyses in order to quantify the contributions of various factors to the predicted health risks. This information enables the modification of processes and implement abatement techniques to reduce risks prior to the construction and operation of a facility.

However, since health risk assessments do not provide information about the existing health status of the community, health risk assessment modelling does not provide information that is directly applicable to the development of solutions to existing community health not uniquely associated with a particular source of substances. Therefore, even though the risk assessment results provide reliable estimates of potential risks to the community from specific sources, concerns will remain in the community about the continued occurrence of health issues because of the wide array of factors responsible for human diseases.

Public Health Assessment provides information about the public health status, issues and concerns in a community, enables comparisons of health status between communities, focusses on the etiology of the diseases identified, and places a perspective on the various possible causes of, or contributors to, the existing health issues in the community. Health issues are a fact of life in all communities. People routinely have a variety of diseases, most of which can be caused by a myriad of factors. In order to do something about existing disease to improve the health of a community, it is necessary to understand the health issues of concern, their rate of occurrence and the possible contributions of the different responsible or causal factors.

There are a large number of factors responsible for human diseases, including:

i) genetics (familial inheritance of factors affecting susceptibility to disease);
ii) lifestyle factors (smoking, alcohol consumption, recreational drug usage, diet, amount of exercise);
iii) indoor air quality (both at home and at work);
iv) outdoor air quality;
v) a wide variety of natural substances in the indoor and outdoor environment (naturally occurring chemicals, moulds, dusts, plant pollens);
vi) various emissions related to general societal activities (traffic, building heating/cooling, long-range transport of air pollutants, population density);
vii) substances entering the environment from the array of industrial/municipal activities typical of modern communities.

Risk attribution techniques use the best available medical to provide an understanding of the relative contributions of these different factors to the causation of the health issues and diseases in a community. Risk attribution is an estimate of the contribution of the different factors that can cause disease relative to the total incidence of that particular disease in the community. Disease incidence is also compared between communities to enable the identification of potential unique issues relevant to one community.

Community Health Programs based on the Public Health Paradigm involve the integration of the information obtained through health risk assessment models applied to various point sources, and through public health assessment to enable the determination of the relative causal attributions of the diseases in a community. These sources of information, plus the specific requirements of the community, are combined to enable the development and prioritization of initiatives to improve the health status of the community. If a Community Health Program were to be conducted for Saint John, the information from the PHRA of the IOL Refinery Upgrade would be directly applicable. To complete the information needed for the application of the Public Health Paradigm in order to develop actions and interventions to improve the health of people in Saint John, additional health risk assessments are needed on other industrial facilities. Moderate expansion of the Public Health Assessment would be also be required.

The Community Health Program, conducted through the CHC, would use the results of health risk assessment models, public health assessment of disease status and risk attribution methods to prioritize, develop and implement specific public health management initiatives. The CHC would also monitor the results of the management initiatives, and institutes modifications and updates to ensure that the program remains effective in the improvement of the health of the public over time. Participation by all stakeholders through a Public Health Program provides a mechanism for achieving a balance in stakeholder inter-relationships in the region, fostering a more sustainable environment, improved quality of life in the community and increased productivity and profitability of the operating facilities in the region.

L-1.6 References

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APPENDIX M

GLOSSARY

M-1.0 GLOSSARY

This glossary contains definitions for commonly used public health risk assessment-related terms. These definitions are not all-encompassing, nor should they be construed to be "official" definitions. For terms that are not included in this glossary, it is recommended that the reader refer to standard health science, biostatistical, and medical textbooks and dictionaries.

Additive effect (additive toxicity): An effect that is the result of two chemicals acting together and that is equal to the sum of the effects of the chemicals acting separately.

Adverse effect: An undesirable or harmful effect to an organism, indicated by some result such as death, altered food consumption, altered body and organ weights, altered enzyme concentrations or visible pathological changes.

Aerosol: Small particles that are finely dispersed in a gaseous form.

Attributable risk: The difference between risk of exhibiting a certain adverse effect in the presence of a substance or condition and that risk in the absence of the substance or condition.

Attributable risk proportion: The proportion of exposed cases for whom the disease is attributable to the exposure.

Background concentration (environmental): The concentration of a chemical in a similar area to the site being evaluated in the risk assessment, but that is not affected by industrial emissions.

Background: An area not affected by chemicals released from the site under evaluation.

Bioaccumulation: The process by which organisms retain chemical contaminants in their tissues at levels greater than that in the ambient environment.

Bioavailability: The degree to which a substance becomes available to the target tissue after administration or exposure.

Biomagnification: The process by which chemicals concentrate or accumulate within organisms that are higher in the food chain, than in organisms that are lower in the food chain.

Cancer: A disease characterized by the rapid and uncontrolled growth of aberrant cells into malignant tumours.

Cancer Risk Level (CRL): The predicted risk of an individual in a population of a given size developing cancer over a lifetime. The CRL is expressed as the prediction that 1 person per ***n*** people would develop cancer, where the magnitude of ***n*** reflects the risks to that population; for example, if the CRL is 2 person per 100,000, the predicted risks of any individual developing cancer would be higher than if the CRL is 1 per 100,000.

Carcinogen: A chemical that is reactive or toxic enough to act directly to cause cancer.

Chronic toxicity: The development of adverse effects after an extended exposure (conventionally at least one-tenth of the expected life span of an organism), to relatively small quantities of a chemical.

Chronic: A relatively long duration of time.

Composite Receptor (Lifetime Receptor): A receptor that is evaluated through their whole lifetime, from when he/she is an infant, through childhood to when he/she is an adult in old age; used to evaluate possible lifetime risks associated with carcinogenic (cancer-causing) chemicals.

Concentration: The amount of chemical or substance in a given environmental medium (air. water, soil, sediment). Concentration is typically expressed in units such as mg/L (in water), mg/kg (in soil or food) and mg/m^3 (in air).

Dose: The amount of chemical taken into the body. Considered a measure of chemical exposure. Generally expressed as mg chemical per kg body weight per day (mg/kg/day).

Dose-response: The quantitative relationship between the exposure of an organism to a chemical and the extent of the adverse effect resulting from that exposure.

Endpoint: A response measure in a toxicity or epidemiology study.

Estimate: Any numerical quantity computed from a sample of data. For example, a sample mean is an estimate of the corresponding population mean.

Exposure: The condition of being in contact with a chemical substance.

Exposure assessment: The process of measuring or estimating the intensity, frequency and duration of human exposure to a chemical present in the environment or of estimating possible exposures that might arise from the release of chemicals into the environment.

Exposure limit: The dose of each chemical to which individuals may be exposed on a daily basis without observing adverse health effects, or where the risk of incurring adverse health effects is considered to be at an acceptable level. May be expressed as a reference dose (RfD) for threshold-response chemicals or as a risk specific dose (RsD) for non-threshold response chemicals.

Exposure pathway: The route by which a receptor comes into contact with a chemical. Examples of exposure pathways include the ingestion of water, food and soil, the inhalation of air and dust, and absorption of air and dust through the skin.

Exposure Ratio Value (ER value): A comparison between the total exposure from all predicted exposure pathways and the exposure limits for chemicals of concern. This comparison is calculated by dividing the predicted exposure by the exposure limit. This value provides an estimate of the degree of risk associated with the chemicals being evaluated in the risk assessment.

Exposure route: The way in which a chemical moves from the environmental or exposure medium into the body. For chemicals in the environment, the major routes are ingestion (oral route), inhalation, and absorption through the skin (or dermal contact).

Extrapolation: An estimation of a numerical value of an empirical (measured) function at a point outside the range of data which were used to calibrate the function. For example, the quantitative risk estimates for carcinogens are generally low-dose extrapolations based on observations made at higher doses.

Human health risk assessment: The process of defining and quantifying risks and determining the acceptability of those risks to human life based on measured or predicted future chemical concentrations in the environment.

Incidence: The number of new cases of a disease within a specified period of time.

Incidence rate: The ratio of the number of new cases over a period of time to the population at risk.

LOAEL (lowest-observable-adverse-effect level): The lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group.

log Kow: Octanol/water partition coefficient. The ratio of a chemical's solubility in n-octanol and water at equilibrium. This parameter is used to predict the potential for a chemical to partition to water or lipid phases. Generally, a log Kow value >4 indicates that a chemical is more lipid than water-soluble.

Measurable adverse health effect: an adverse health effect which can be measured statistically within a population.

Model: A mathematical function with parameters which can be adjusted so that the function closely describes a set of empirical or "real-world" data.

Multistage model: A dose-response model often expressed in the form $P(d) = 1 - \exp\{-[q(0) + q(1)d + q(2)d{*}{*}2 + \ldots + q(k)d{*}{*}k]\}$ where $P(d)$ is the probability of cancer from a continuous dose rate d, the $q(i)$ are the constants, and k is the number of dose groups (or, if less, k is the number of biological stages believed to be required in the carcinogenesis process). Under the multistage model, it is assumed that cancer is initiated by cell mutations in a finite series of steps. A one-stage model is equivalent to a one-hit model.

Non-detectable: A concentration that is below the detection limit of the equipment which is attempting to measure it. This means that the actual chemical concentration is somewhere between zero and the detection limit of the equipment used to measure it, but current technology cannot quantify the actual concentration. It is generally recommended that these values be included in the risk assessment as values at one half of the detection limit.

Non-Threshold Response Chemicals (typically carcinogens): Chemicals for which there is no dose-response threshold. This means that any exposure greater than zero is assumed to cause some type of response, or damage. This relationship is used for chemicals which can cause cancer by damaging genetic material (*e.g.*, chemicals in the benzo[a]pyrene group). Since, in theory, any exposure has the potential to cause damage, it is necessary to define an "acceptable" degree of risk associated with these types of exposures. This "acceptable" degree of risk is usually defined as a risk of one-in-one hundred thousand to one-in-one-million. The level of risk is set by regulatory agencies, and can be better explained as the dose rate that may cause an increased risk of cancer in one person out of one hundred thousand people, or one person out of one million people. Exposure limits derived for non-threshold response chemicals are called risk specific doses (RsD). In the case of common air pollutants (which are non-carcinogens), it must be recognized that there is some debate within the scientific community with respect to whether they exhibit a threshold in their dose-response relationships.

NOAEL (no-observable-adverse-effect level): An exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control; some effects may be produced at this level, but they are not considered as adverse, nor precursors to adverse effects. In an experiment with several NOAELs, the regulatory focus is primarily on the highest one, leading to the common usage of the term NOAEL as the highest exposure without adverse effect.

Particulate Matter (PM): All airborne solid or liquid particles that are microscopic in size. Particle sizes may range from 0.005 μm to 100 μm.

Pathway (exposure): A way in which a chemical may be transferred from the environment to humans.

PM_{10}: Particles that are less than 10 μm in diameter. Also referred to as "inhalable" particles.

$PM_{2.5}$: Particles that are less than 2.5 μm in diameter. Also called "fine" or "respirable" particles.

Population Attributable Risk: The attributable fraction in the population, or the population excess rate.

q1*: Upper bound on the slope of the low-dose linearized multistage procedure. This procedure is a modified form of the multistage model (see Multistage Model). The constant q1 is forced to be positive (>0) in the estimation algorithm and is also the slope of the dose-response curve at low doses. The upper confidence limit of q1 (called q1*) is called the slope factor.

Qualitative risk assessment: An analysis that is a qualitative statement of risks, based on historical information, circumstantial evidence of contamination or limited sampling information. Only a qualitative statement of uncertainty is possible and uncertainty is generally high.

Quantitative risk assessment: An analysis that is a quantitative statement of risks, based on chemical concentrations measured in various media at the site under consideration and background areas. A quantitative risk assessment produces numerical risk estimates for various exposure scenarios.

Receptor: A person (*e.g.*, toddler, child, adolescent, adult) or animal species which lives in the area under consideration and is or could potentially be exposed to the chemicals of concern.

Reference dose (RfD): The maximum recommended daily exposure for a chemical exhibiting a threshold (highly nonlinear) dose-response based upon the NOAEL or LOAEL determined for the chemical from human and/or animal studies and the use of an appropriate safety factor. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Reference Concentration (RfC): Similar to an RfD with the exception that the RfC is expressed as a continuous air concentration, rather than a daily dose. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime.

Relative risk (sometimes referred to as risk ratio): The ratio of incidence or risk among exposed individuals to incidence or risk among nonexposed individuals.

Risk (human health): The likelihood, or probability, that the toxic effects associated with a chemical will be produced in a population of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect in a given time, and the total number of individuals exposed to the factor.

Risk estimation: The integration of the exposure assessment and toxicity assessment to evaluate the likelihood of adverse human health effects associated with exposure to an environmental chemical.

Route (exposure): The way in which a chemical moves from the environmental or exposure medium into the body. For chemicals in the environment, the major routes are ingestion (oral route), inhalation, and absorption through the skin (or dermal contact).

RsD (Risk Specific Dose): The exposure limit determined for chemicals assumed to cause cancer by altering genetic material (genotoxic, non-threshold carcinogens). An RsD is a function of carcinogenic potency (q_1^*) and defined acceptable risk (*e.g.*, one in one hundred thousand, one in one million). Regulatory agencies in Canada define an RsD for human exposure at a risk of one in one hundred thousand (10^{-5}) as $RsD = 1x10^{-5} \div q_1^*$.

Slope Factor: The slope of the dose-response curve in the low-dose region. When low-dose linearity cannot be assumed, the slope factor is the slope of the straight line from 0 dose (and 0 excess risk) to the dose at 1% excess risk. An upper bound on this slope is usually used instead of the slope itself. The units of the slope factor are usually expressed as 1/(mg/kg-day).

Standardized mortality ratio (SMR): The ratio of observed deaths to expected deaths.

Threshold dose: The dose of a chemical below which no adverse effect occurs. The existence of such threshold is based on the fundamental tenet of toxicology that effect is directly related to the dose.

Threshold-Response Chemicals (non-carcinogens): Chemicals for which there is a dose-response threshold below which no adverse effects would be expected to occur. This relationship is true for all chemicals which do not cause cancer by altering genetic material (*e.g.*, dioxins/furans, most metals, with the exception of arsenic and beryllium). Exposure limits derived for threshold-response chemicals are called reference doses (RfD), acceptable daily intakes (ADI) or permissible daily intakes (PDI).

Total Suspended Particulates (TSP): Refers to airborne particles with diameters less than 100 μm that are known to be relatively inert, both chemically and biologically.

Toxicity: The production of any type of damage, permanent or temporary, to the structure or functioning of any part of the body. The conditions of exposure under which toxic effects are produced, the size of the dose and the duration of the dosing needed, vary greatly among chemicals.

Toxic Equivalency (TEQ): To facilitate the comparisons of isomers, congeners and chemicals acting via a similar toxic end point (*e.g.*, chlorinated dioxins and furans, PAHs), a toxic equivalency approach is used. This approach is based on the expression of the toxic potency of the different isomers and congeners in terms of equivalents of the most toxic member of that group and then added together.

Toxic Potency: The relative degree of toxicity among chemicals at the same concentration. For example, the toxic potency of chemical A would be higher than that of chemical B if toxic effects are produced at a lower concentration of chemical A than of chemical B.

Toxicology: The study of the adverse effects of chemicals on living organisms.

Uncertainty factor (or safety factor or extrapolation factor): One of several, generally 10-fold factors, used in operationally deriving the Reference Dose (RfD) from experimental data. UFs are intended to account for (1) the variation in sensitivity among the members of the human population; (2) the uncertainty in extrapolating animal data to the case of humans; (3) the uncertainty in extrapolating from data obtained in a study that is of less-than-lifetime exposure; and (4) the uncertainty in using LOAEL data rather than NOAEL data.

Unit Risk: The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 ug/L in water, or 1 ug/m^3 in air.

Volatile Organic Compounds (VOC): Organic compounds that exist as vapours or gases under ambient environmental conditions.

Weight-of-evidence for carcinogenicity: The extent to which the available biomedical data support the hypothesis that a substance causes cancer in humans.